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MONOCOQUE STRUCTURE FOR THE SKITTER THREE-LEGGED WALKER

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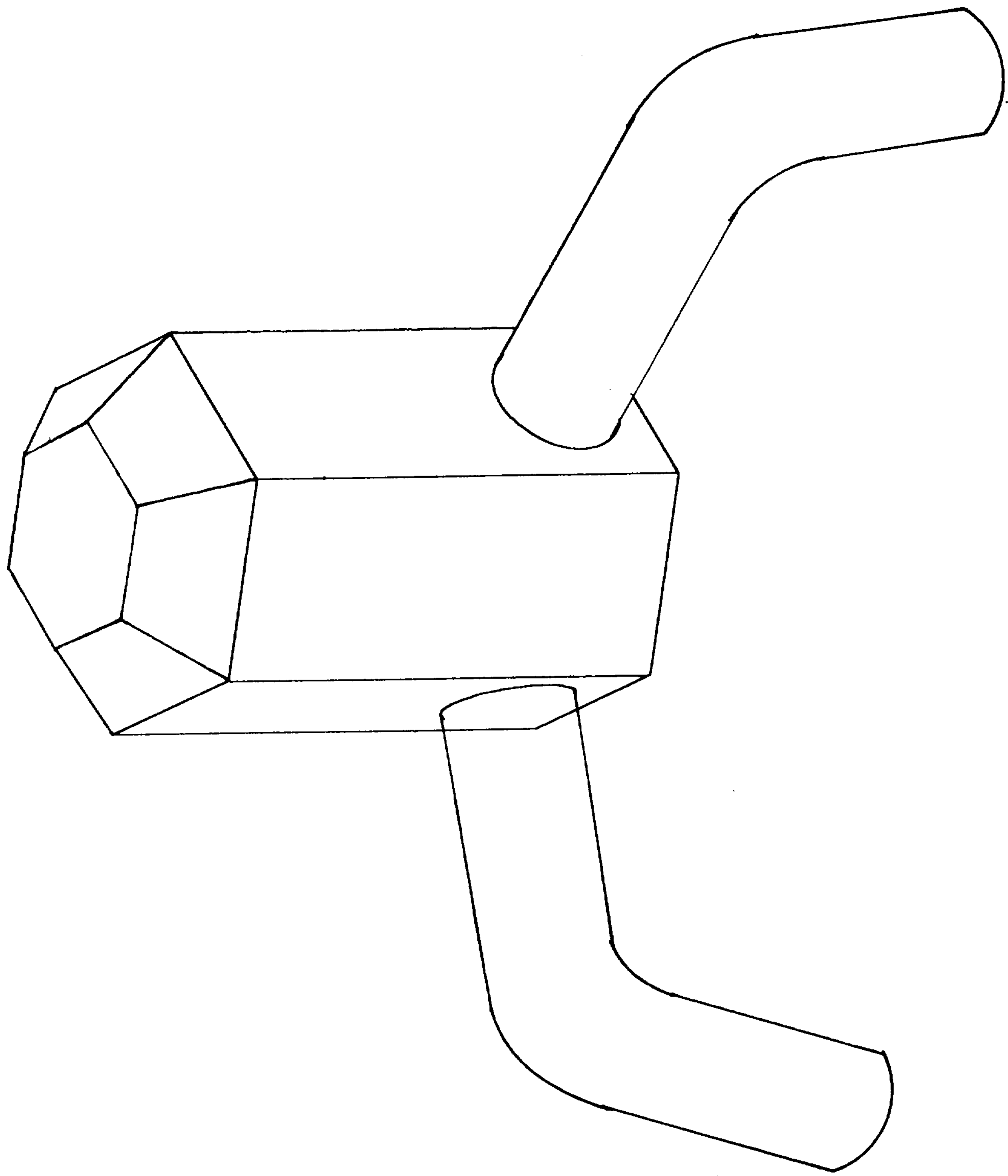
FIG. 1



ABSTRACT

The SKITTER II design is a monocoque version of the proposed lunar three-legged walker. By the definition of monocoque, the body and legs are a shell with no internal ribbing or supports added for absorbing stresses. The purpose of the monocoque is to encase the elements used for power transmission, power supply, and control of the motion.

The material for the structure is a vinyl ester resin, Derakane 8084. This material is easily formable and locally obtainable. The body consists of a hexagonally shaped cylinder, with truncated hexagonal pyramids on the top and bottom. The legs are eight inch diameter cylinders. The legs are comprised of a tibia section and a femur section. The SKITTER II is powered by six actuators which provide linear forces that are transformed into rotary torques by a series of chains and sprockets. The joints connect the femur to the body and the tibia to the femur. Surrounding the joints are flexible rubber hoses that fully encase the chains and sprockets.

The SKITTER II is capable of walking upside down, righting itself after being overturned, and the ability to perform in many environments. Applications for this walker include lunar transport or drilling, undersea exploration, and operation in severe surroundings such as arctic temperatures or high radiation.

PROBLEM STATEMENT

Our group was assigned the task of developing a monocoque structure compatible with the SKITTER walker. The problem also contained a number of constraints and performance goals. Meeting the constraints was considered to be mandatory while meeting the performance goals was to be considered an added incentive.

The given constraints covered all facets of the problem. The structure was to be a true monocoque design, meaning no internal ribbing was to be used for structural integrity. Also, this monocoque structure must be able to support 300 pounds. The materials used must be locally obtainable and easily formable. The material used for the actual structure must have at least a ten to one strength to weight ratio. Dynamically, SKITTER II was to have a 120 degree of motion from the body to the end of the tibia. These constraints provided a framework on which to base our design, however the constraints were not our sole design objectives.

In addition to the constraints, a number of performance objectives were set in an attempt to improve the monocoque SKITTER II over existing designs. The walker should not only be self righting; it should also be able to walk upside down. To take full advantage of the monocoque design, all mechanisms should be located inside the structure. The strength to weight ratio should be increased as much as possible without dramatically increasing cost. Finally, the walker should be easy to build. Using the problem statement, constraints, and goals as guidelines our group developed the following design.

DESCRIPTION

GENERAL

The SKITTER walker is a three-legged transport vehicle designed for multipurpose usage on the lunar surface. It is highly flexible, capable of a wide assortment of tasks beyond transportation. It may also be used as a cargo carrying device as well as a host for a large number of digging, drilling and lifting implements. (See figure 1).

The monocoque SKITTER II, while similar to the original SKITTER, offers several advantages over existing designs. The monocoque design consists of a hexagonally shaped body with cylindrically shaped legs, made of fiberglass. Movement of the legs is achieved through linear actuators which provide rotation through a set of sprockets and chains. The major sections of SKITTER II, materials, geometry, and power transmission, are described in the ensuing paragraphs.

MATERIALS

The material chosen for the SKITTER II shell was Derakane 8084, a vinyl ester resin. While similar to common boat fiberglass, Derakane 8084 possesses superior material properties.

BODY GEOMETRY

The body geometry for SKITTER II is a hexagonal cylinder. It has flat faces on which the actuators can be easily mounted inside the body (See Figure 2). The three faces on which the actuators and sprocket shafts are mounted contain aluminum brackets which are bolted to the inside of the body. The aluminum bracket consists of two u-shaped pieces, connected side by side, perpendicularly extending from the face of the body (See Figure 3). Each face is 30.5 inches tall and 12 inches wide. The top and bottom faces are truncated hexagonal pyramids to accommodate the crane and robot arm attachments (See Figure 4).

LEGS

SKITTER II has three identical legs, each comprised of a femur and a tibia, spaced 120 degrees apart. The femur has a circular cross section, eight inches in diameter, while the tibia has a four inch cross section, both with a shell thickness of one-eighth of an inch. The legs are forty inches in length, evenly divided between the femur and tibia. The femur houses the chain drive for the tibia, while the tibia is completely hollow.

JOINTS

Connecting the femur and the body and the femur and the tibia are the joints. The joints transmit the generated torques from the power transmission system to the leg parts. The knee joints consist of an aluminum sleeve bonded and bolted into the end of each leg part. Extending from the sleeve are two (1.5 inches long x 1.0 inch tall x 0.25 inches wide), parallel bars, diametrically opposite from each other. A five-eighth's inch shaft between the two bars rotates freely. A sprocket is fixed to this shaft . The two tibia bars are then fixed to the shaft so that, as the sprocket turns, the tibia pivots. The entire joint is then covered by a flexible rubber hose clamped to the femur and tibia at the metal sleeve to prevent contamination by foreign material such as lunar dust. The hip joint connecting the body and the femur is quite similar to the knee joint. However, the hip joint does have two major differences. First, the bars extending from the body are attached to a bracket embedded in the body wall. Also, the shaft between the bars extending from the body contains an extra idler sprocket for torque transmission to the tibia.

POWER TRANSMISSION

Fifteen-hundred pound forces developed by six linear actuators are transformed by a series of chains and sprockets into the forces and torques necessary for SKITTER II to walk. The majority of the power transmission equipment is located inside the body. The actuators, and the accompanying power transmission assemblies, one for each joint in each leg, are fastened to the walls of the body (See Figure 5). The paired power transmission assemblies for each leg are located 120

degrees apart, affixed to the same faces of the body to which its accompanying leg is attached. The actuators for the femur-body hip joint provide a linear force to a primary chain that is strung between an 8.358 inch pitch-diameter, force transmitting sprocket and a 1.449 inch pitch-diameter, idler sprocket. The eight inch sprocket is fixed to a common shaft along with a smaller, 1.775 inch pitch-diameter, step-down sprocket (See Figure 6). The 1.775 inch sprocket drives a secondary chain that is strung to another 1.775 inch sprocket at the hip joint. The joint sprocket is fixed to the hip joint shaft and provides the torque described above (See Figure 7).

For tibia movement, the large sprocket for the primary chain has a 4.183 inch pitch diameter, while the idler sprockets and the step-down sprockets are 2.721 inch sprockets (See Figures 8 & 9). The secondary chain runs from the body to the hip joint, around the outer sprocket of a double sprocketed, 2.721 inch sprocket. Around the inner sprocket of the double sprocket is a chain that runs to the femur-tibia knee joint. The sprocket at the knee joint is identical to the step-down sprocket. This complex system is used to change the linear motion of the actuators into the rotary motion necessary to move the joints. (See Figure 10)

PERFORMANCE

The monocoque SKITTER II fulfills a large number of performance objectives. Most importantly, the SKITTER II walker is a true monocoque design, with no internal ribbing required for support. The fully enclosed shell houses all control and drive mechanisms. This feature provides protection from outside elements and enables SKITTER II to operate in a number of harsh environments. The structure can statically support more than three hundred pounds and has a greater than ten to one strength to weight ratio. The materials that exceed the strength requirements also are easily formable and locally available. The range of motion for each femur joint is 109 degrees and, for each tibia joint, the range of motion is 219 degrees. The combination of the two joints allow the SKITTER II to walk upside down. The attainment of the listed performance objectives illustrates the versatility of the monocoque design.

ANALYSIS

MATERIALS

Derakane 8084, a homogenous fiberglass, is highly chemically resistant and has excellent physical properties. When compared with a standard epoxy, Derakane 8084 possesses greater elasticity while maintaining comparable tensile strengths. The tensile strength is 10,000 psi. and the percent elongation is in the range of ten to twelve. The tensile elongation is twice that of standard vinyl ester resin. The material's benefits include greater resistance to failure from thermal expansion or impact. These characteristics are highly desirable in a lunar environment. The mixture of an epoxy backbone, combined with vinyl groups and a styrene monomer, provides high reactivity and low viscosity that are not found in standard fiber-reinforced plastics. These properties make Derakane 8084 easier to form than other materials investigated. The volumetric weight of the material is based on a 1/8 inch thickness. For a square foot of Derakane 8084, the weight is approximately 1.0 pounds. The total weight of the material is 28 pounds. All of the mentioned characteristics, plus a strength to weight ratio of 12.5 to 1, made Derakane 8084 our selection for a material. (See Appendix 1)

BODY GEOMETRY

The body geometry for SKITTER II is a hexagonal cylinder. The hexagonal shape enables the stresses to be distributed evenly, resulting in fewer stress concentrations than geometries such as cubes or triangles. A sphere would be the optimum geometry for reducing stress concentrations, but the curved face would make the attachment of the power transmission elements more difficult than the flat faces of the hexagon. The flat faces on which the power transmission elements are attached have a bolted, u-shaped aluminum bracket for strength support. The brackets are bolted so that the bolts will absorb a large portion of the shear. Truncated pyramids are used for the top and bottom faces. The advantage of the truncated pyramid is that the load is more evenly distributed than with a pure flat face. (See Appendix 2A)

LEGS

Three forty-inch long legs are spaced at 120 degree intervals around the body. The twenty inch long femur has an eight inch cross section to house the large chains and sprockets found at the hip joint, while the tibia has a four inch cross section for its smaller joint components. The wall thickness of 1/8 inch was chosen as a result of the stress analysis on the legs. The maximum principal tensile stresses, as determined by a Mohr's circle computation, are 2060 psi. for the femur and 6725 psi. The maximum principal compressive and shear stresses are 2251 psi. (femur), 7113 psi (tibia), and 1139 psi. (femur), 3605 psi. (tibia), respectively. The calculations for these figures were determined via the computer program in appendix 2B. The leg geometry provides a factor of safety of approximately one and a half. The circular cross section was chosen to give a stress distribution that is uniform, and the geometry was selected because of the easy formability. The tibia and femur leg lengths were chosen for their moment arms. The twenty inch lengths give a torque of 522 pound-feet at the hip joint. The use of thirty inch lengths would require nearly 800 pound-feet at the joint.

Sixty inch total length legs result in a dramatic increase of weight and size for the components of the power transmission. This analysis was done in a configuration with SKITTER II's legs fully extended, and the requirement that all the force for lifting must come from the hip joint.

JOINTS

The joints were chosen for their mechanical simplicity. At the knee joint, the rotating shaft connects to the extended bars of the femur with encased bearings on each side. The material for the entire joint is A92014 aluminum alloy. The femur side of the knee joint experiences only compressive stresses from the pulling of the chain on the sprocket. The maximum stress is 9220 psi. On the tibia side of the knee joint, the bars experience a tensile stress of 58.9 kpsi. These stresses occur at the interface between the shaft and the bars. The limiting factor of safety is 1.2. (See Appendix 2C)

POWER TRANSMISSION

In order to develop torques at the joints to move SKITTER II, we chose a system of chains and sprockets to convert the linear motions of the actuators to rotary motions. The six actuators each provide 1500 pounds of force. This force is transmitted through a chain wrapped around two sprockets. For the hip joint, the power transmission sprocket is 8.358 inches in diameter and the idler sprocket is 1.449 inches. A step-down sprocket of 1.775 inches, with a secondary chain wrapped around another 1.7775 inch joint sprocket, is used to create 109.68 degrees of rotation at the hip. The torque generated at the hip joint is 522.38 foot-pounds. Generating this torque, while retaining in excess of sixty degrees of rotation, is a requirement under the worst-case scenario, where all the weight for SKITTER II is distributed among the three legs and all the force to lift a leg must come from the hip joint. This case was a primary constraint for the design.

At the knee joint, the angle of rotation is 219.16 degrees. A 4.183 inch sprocket is used as the power transmission sprocket, while 2.721 inch sprockets are used for the step-down, secondary chain idler, and knee joint sprockets. The torque produced by the tibia power transmission is 261.48 foot-pounds.

The total rotation, from hip joint to the foot is ± 164 degrees from the center line of the joint. This rotation allows SKITTER II to walk upside down, another design objective. (See Appendix 2D)

CONCLUSIONS

The monocoque design for SKITTER II demonstrably satisfies all of the desired performance objectives while delivering a relatively low cost, easy to build, proof of principle model. The body and legs are a true monocoque design, having no internal ribbing for strength or structural support. The monocoque structure is valued for its enclosure of all elements of the power transmission and may include such items as controlling devices or power sources. Harsh environments such as the lunar surface, the arctic, or undersea are operationally possible for SKITTER II.

The walker is made of Derakane 8084, a vinyl ester resin. It is a locally obtainable, easily formable material that exceeds the 10 to 1 strength to weight characteristic desired with a 12.5 to 1 strength to weight ratio. The SKITTER II can statically support 300 pounds, while it weighs approximately 250 pounds. While not a requirement for this analysis, the Derakane also exhibits excellent thermal properties in extreme temperature gradients. The use of a more expensive or more exotic material such as a carbon fiber composite or Kevlar would provide even better characteristics, but was unwanted for this model.

The geometry for the body is a hexagonally shaped cylinder with truncated hexagonal pyramids for the top and bottom faces. This geometry allows for a reduction in stress concentration over such configurations as squares or triangles. The top and bottom enable the stresses from a top or bottom load to be more equally dispersed than if a purely flat surface would be used. The flat surfaces, while not as ideal for reduction in stress concentration as a spherical geometry, do allow for easier attachment of the power transmission elements. The height of the body is 30.5 inches tall, while the greatest width of the entire cylinder is 24.0 inches.

The legs are designed for ease in construction and the best behavior under the widest ranges of loadings. Cylinders provide the best shape for making the model while being able to uniformly distribute radial stresses. The length of forty inches is suitable because it reduces the size and weight of the power transmission system over the originally proposed thirty inches. The eight inch diameter allows the chain and sprockets to move freely, while minimizing size. The tibia could have a much smaller diameter, or taper down to a point, since it houses nothing, but for this model, complex geometries were not considered.

Using the linear actuators as a driving force, the design enables a system of chains and sprockets to provide greater than the 120 degree range-of-motion from body to foot and accomplishes the goal of walking upside down. The power transmission system produces a torque at the hip joint of 522 foot-pounds and a torque at the knee joint of 261 foot-pounds. While these torques fulfill the performance objective of the hip joint alone being able to lift the leg in a fully extended configuration, the system may not be the best possible one to use.

Combining a linear actuator in the hip joint and a rotary actuator in the knee joint would accomplish the performance objectives regarding torques and rotation, and would also reduce the weight necessary for the power transmission system. Also, the combination system would delete some mechanical complexity by the use of the rotary actuator as the joint itself, thus eliminating the need for additional parts that could fail.

RECOMMENDATIONS

The following is a compiled list of recommendations for improving the SKITTER II Walker.

- Use rotary actuators instead of linear ones for either both joints or at least the knee joint. This will reduce the weight and the complexity of the power transmission system. The size of the leg diameters may also be reduced.

- Use sprockets and chains made of lighter weight material, (possibly composites), to further reduce the overall weight of the power transmission system

- Don't have the entire walker a monocoque structure. The tibia, with either our power transmission or one using rotary actuators, does not need to be hollow. This portion of the leg could be a tubular design for easier attachment of peripherals or simply as weight reduction.

- Find a material that has greater properties for specific environments that the walker may be used. For example, using an embedded carbon fiber composite for greater strength or something highly resistant to high heat or radiation is a consideration. The expense will be greater, but the application may call for performance over cost.

- Use elliptical cross section with semi-major axis perpendicular to ground to provide greater resistance to bending. This would also reduce width of legs, whereas the circular cross section allows for height clearance of the chains and sprockets, the width is unnecessarily excessive. Formation of the legs would be more complex.

- Make the body out of a spherical geometry. This will most uniformly distribute the stresses, but will make the attachment of the power transmission components more difficult.

- Find a more protective way of encasing the joints. The dryer-style hose is functional, but a more elaborate system would make the joints less susceptible to damage from a load or impact.

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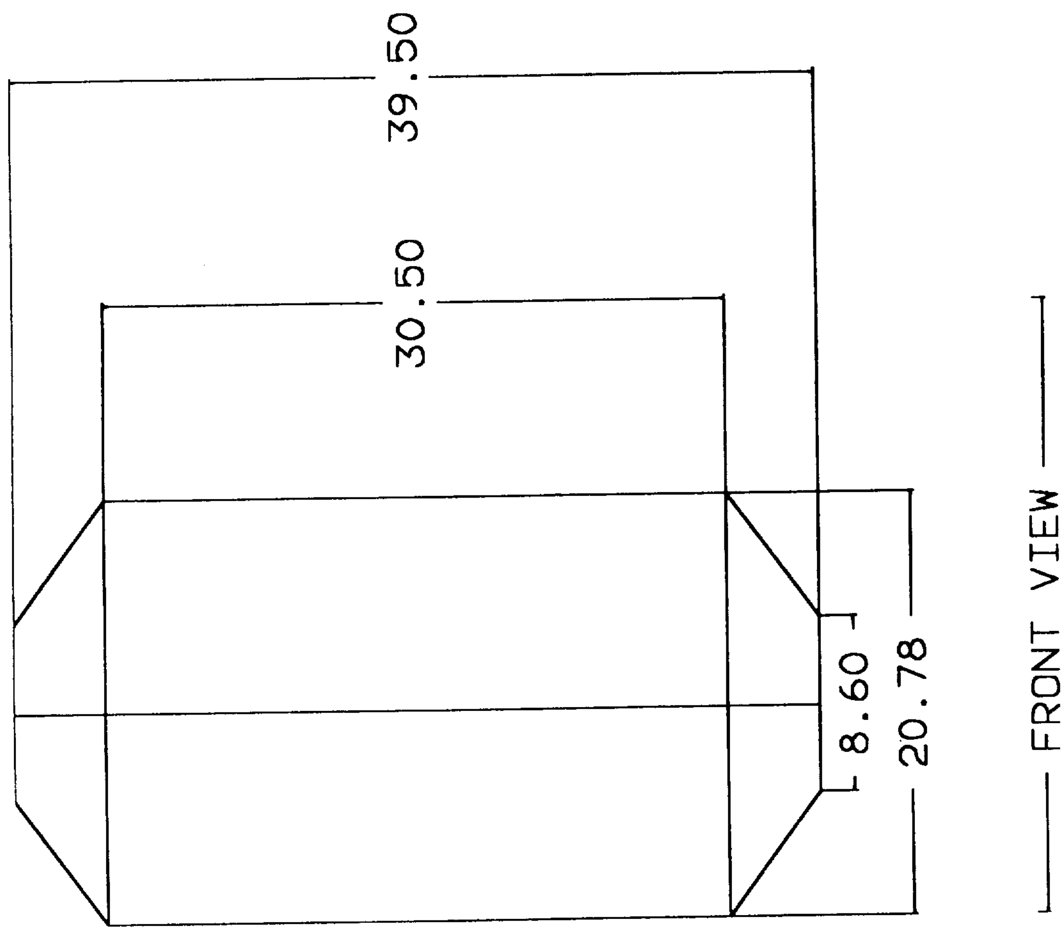
LIST OF FIGURES

FIG. 2



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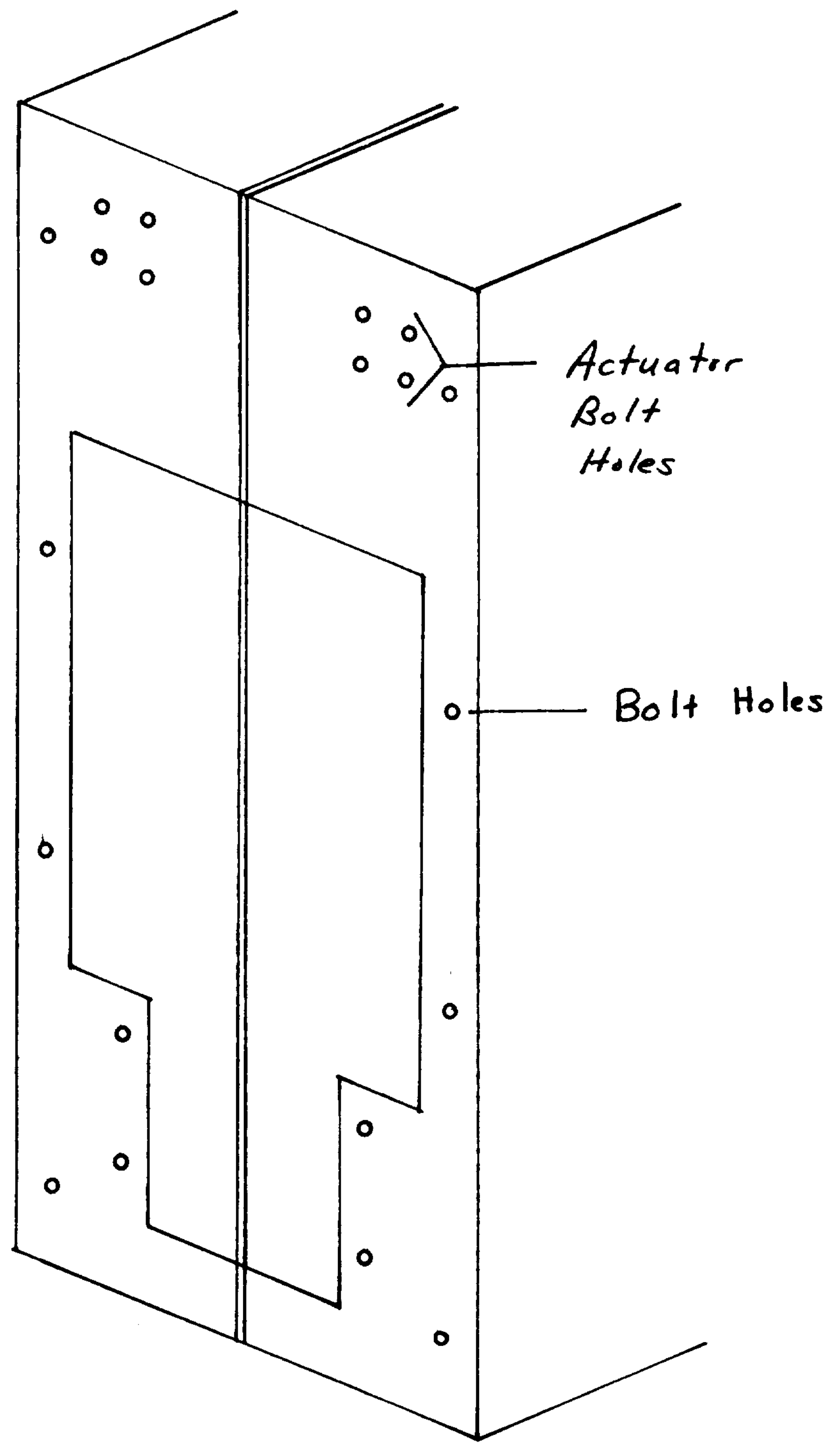


FIG. 4

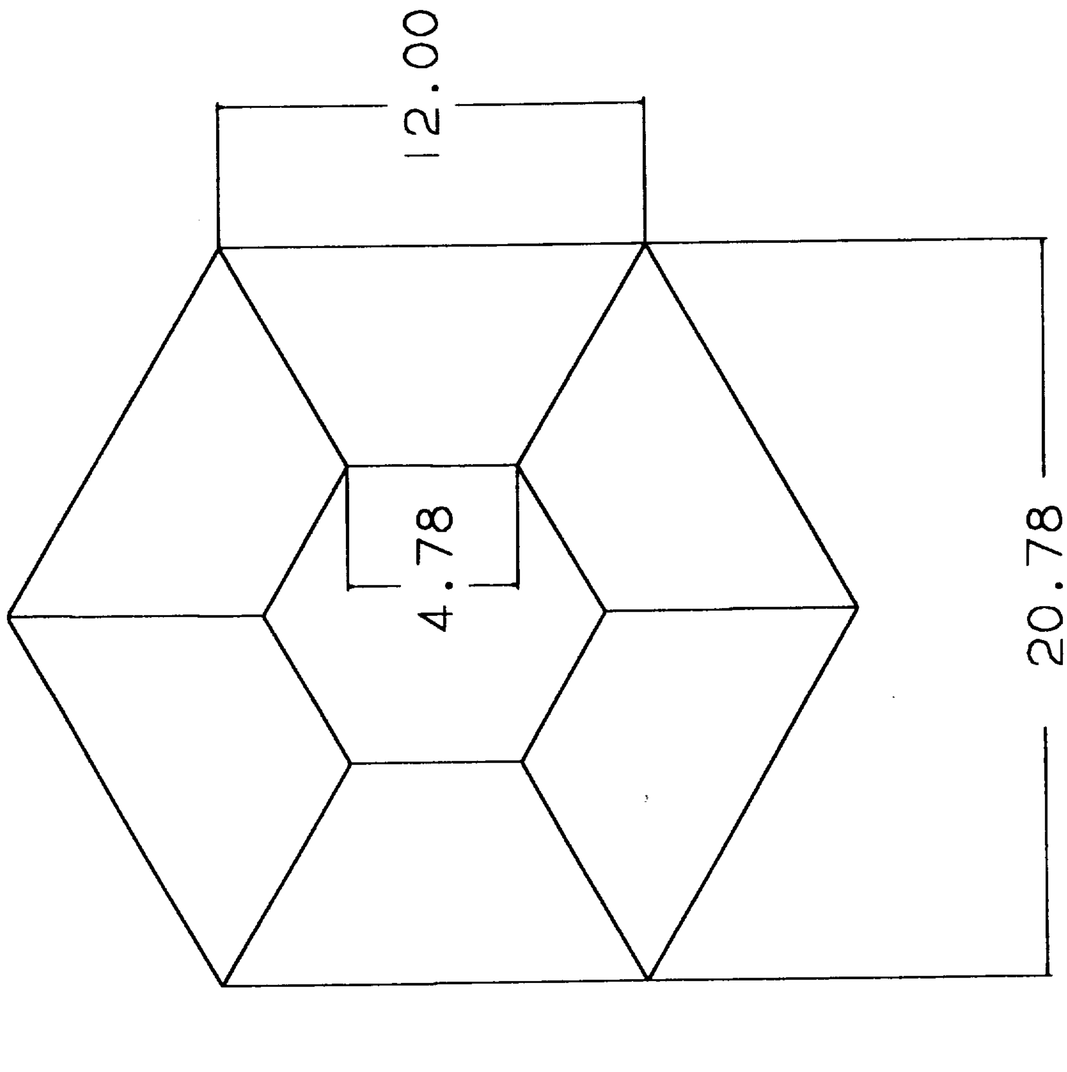
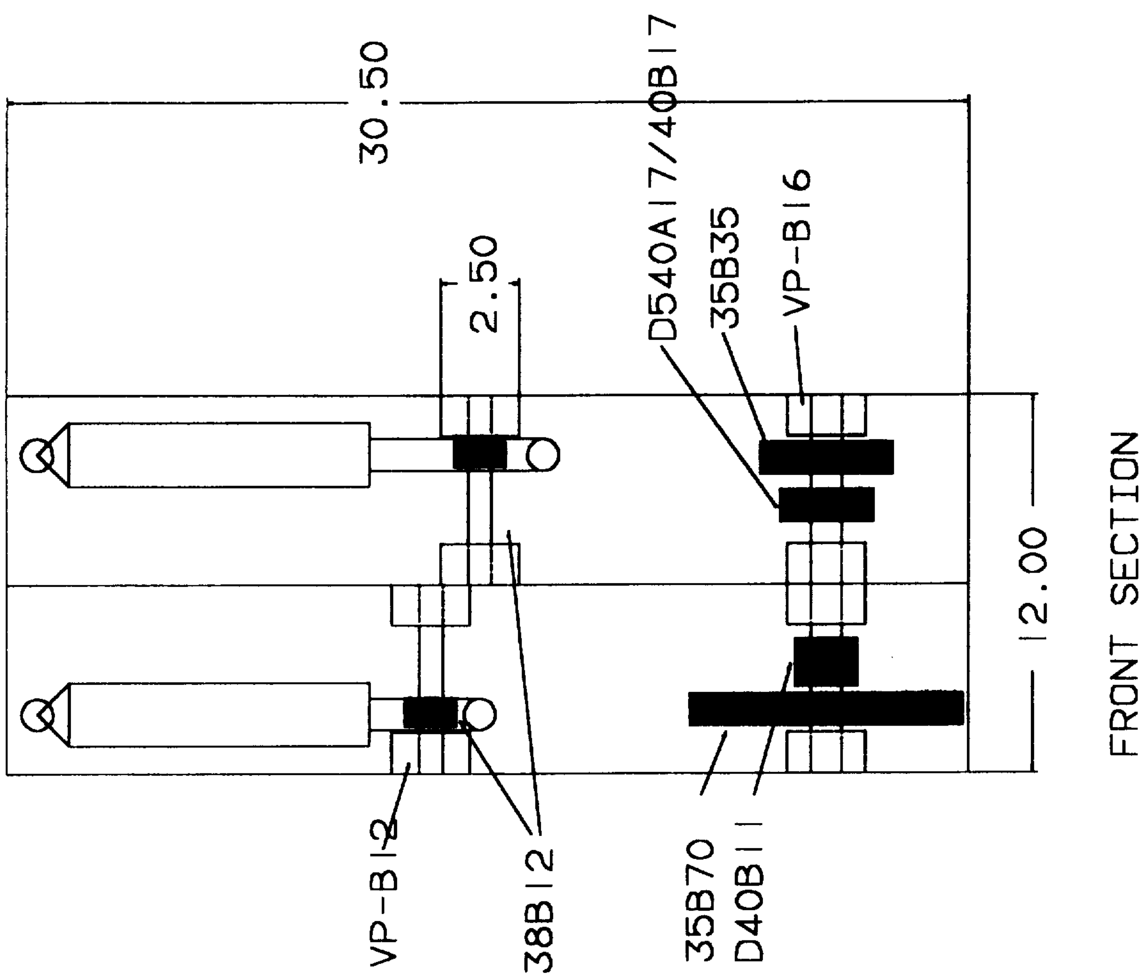
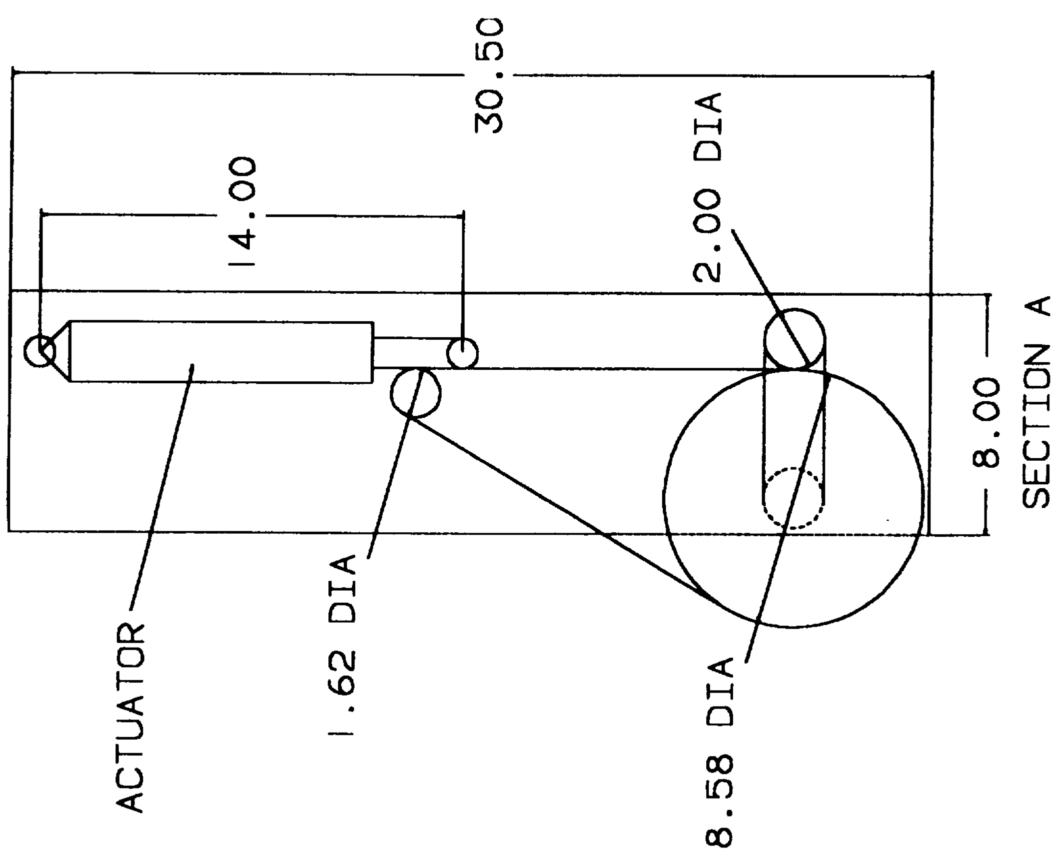


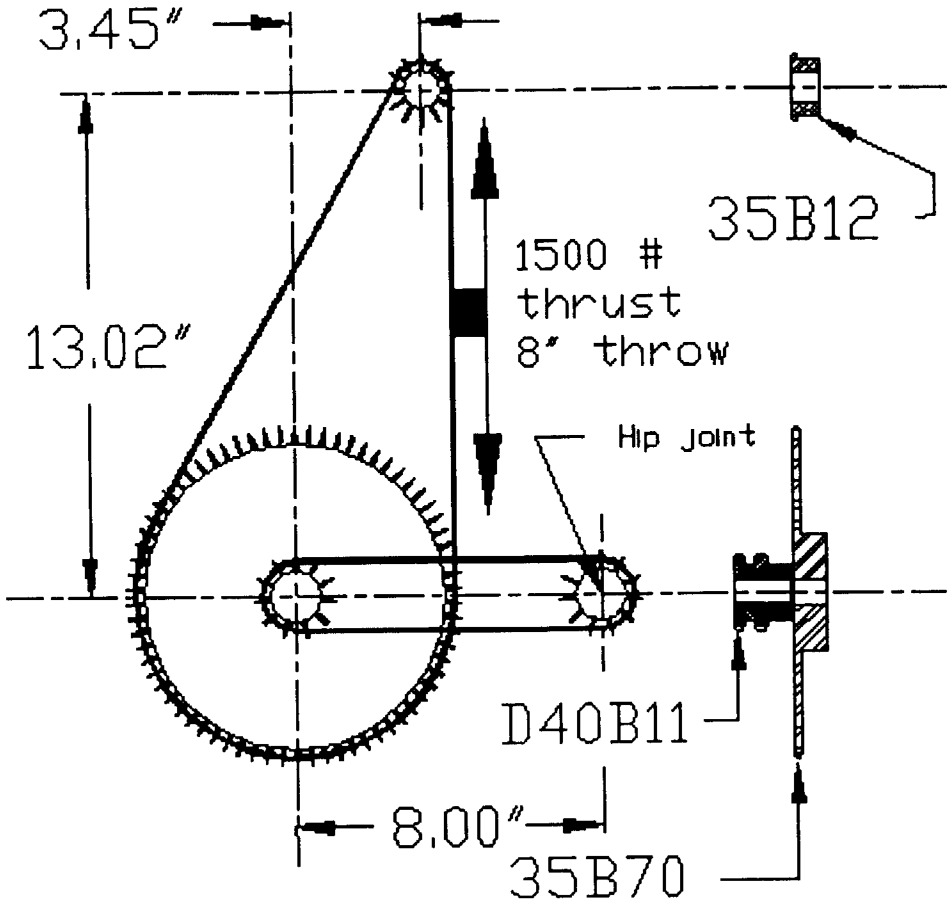
FIG. 5



30.50
D540A17/40B17
2.50
35B35
VP-B16
12.00
FRONT SECTION
VP-B12
38B12
35B70
D40B11

FIG. ~~8~~6





FEMUR DRIVETRAIN

SKITTER II

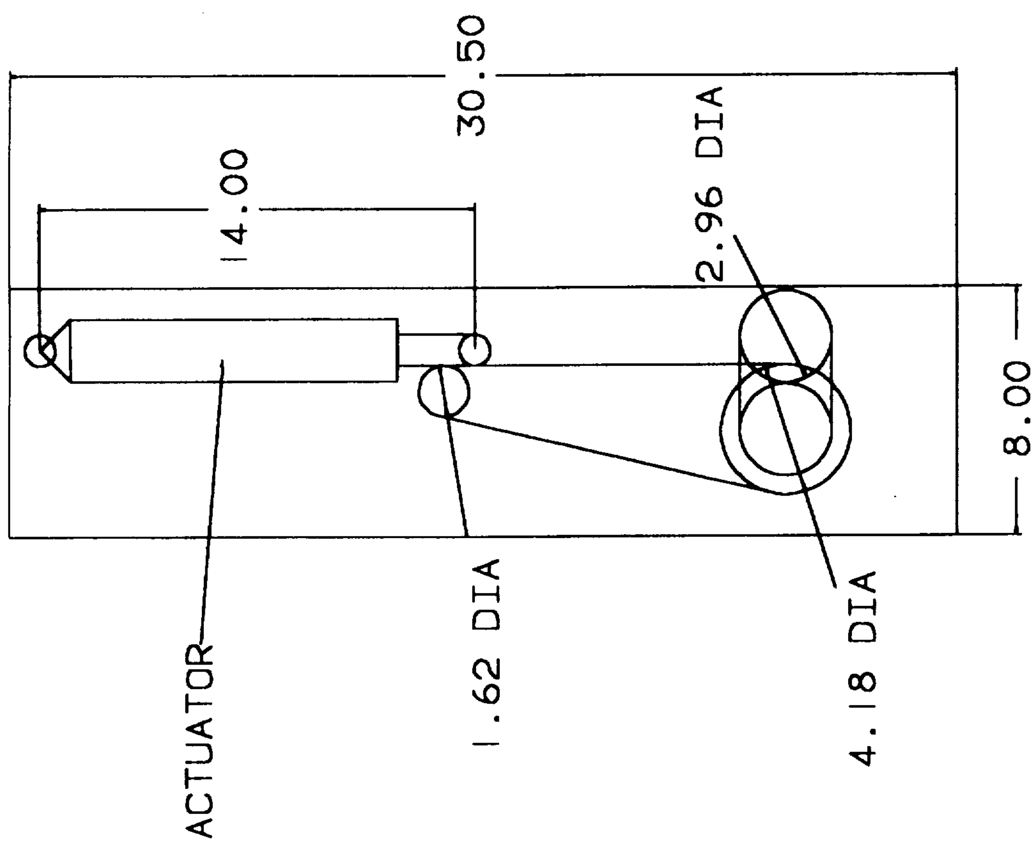
Monocoque Design

NOTE: Bearings and actuators omitted for clarity.

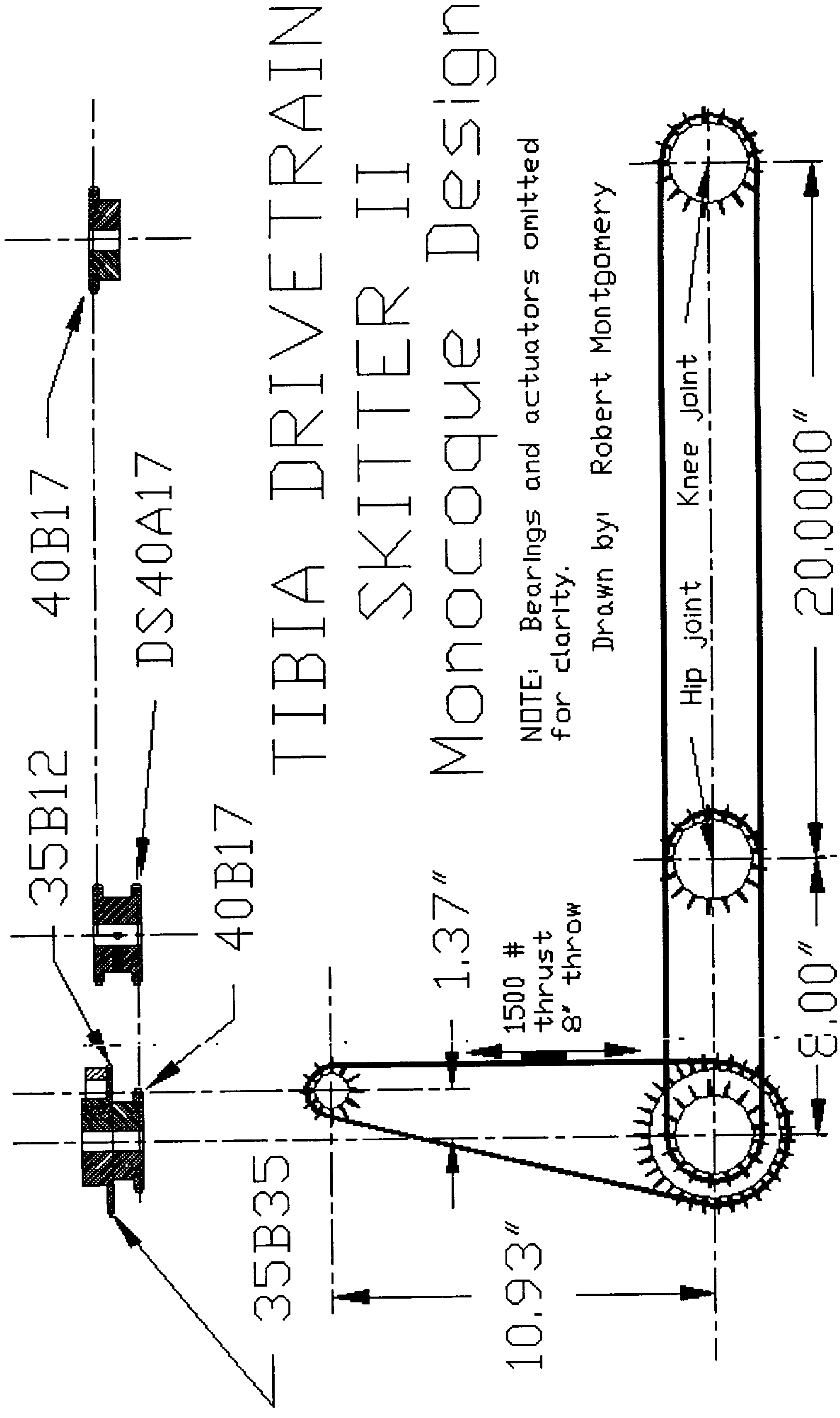
Drawn by: Robert Montgomery

FIG. 7

FIG. ~~6~~ 8

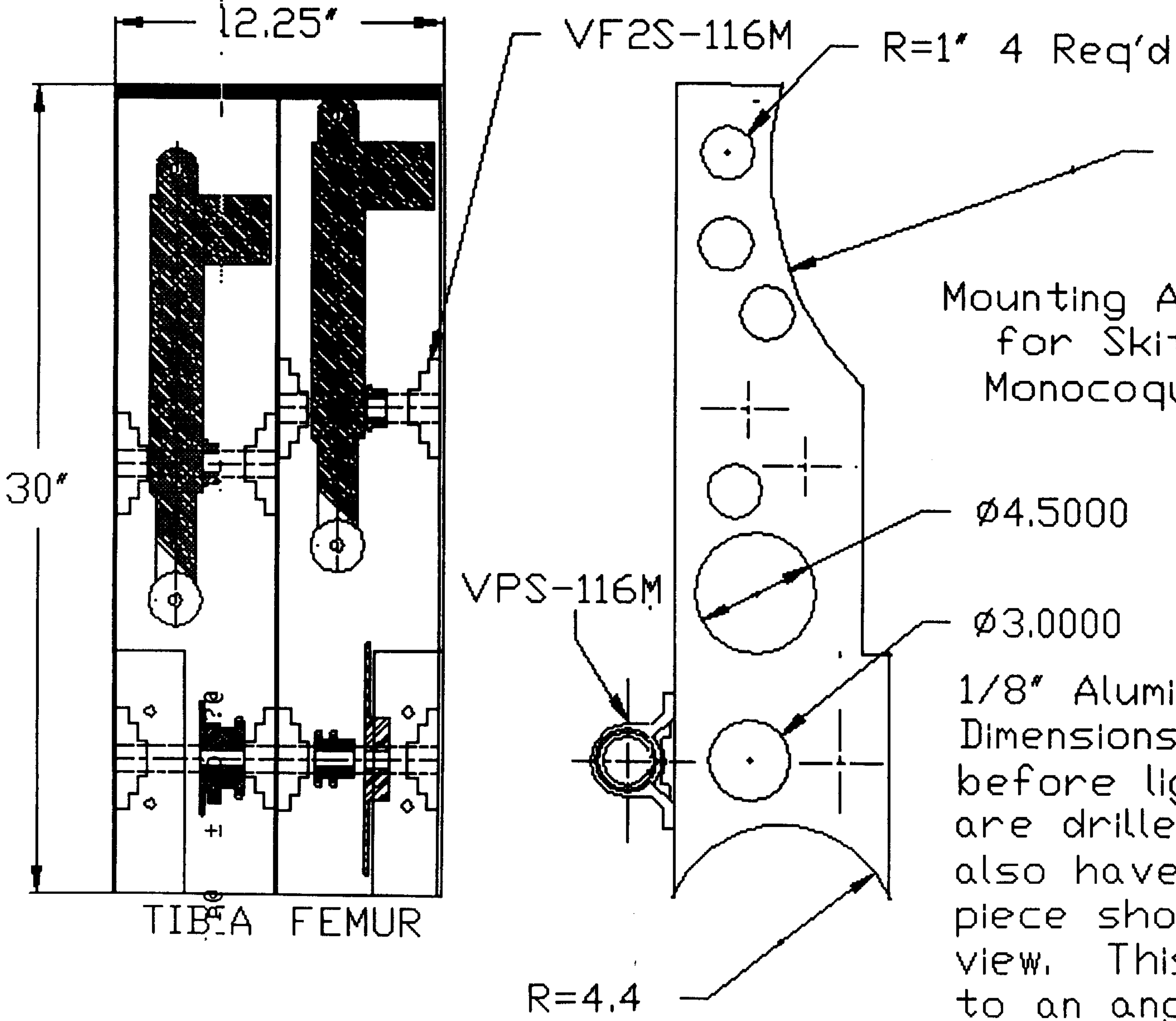


SECTION B



TIBIA DRIVETRAIN
SKITTER II
Monocoque Design
NOTE: Bearings and actuators omitted for clarity.
Drawn by: Robert Montgomery
35B12
40B17
DS40A17
40B17
35B35
1.37"
1500 # thrust
8" throw
10.93"
8.00"
20.0000"
Hip joint
Knee joint

FIG. 9



Mounting Arrangement for Skitter II. Monocoque Design.

1/8" Aluminum plate Dimensions are 8" X 30" before lightening holes are drilled. End plates also have the 12" X 2.5" piece shown in the front view. This should be broken to an angle of 90 deg.

FIG. 10

APPENDIX 1

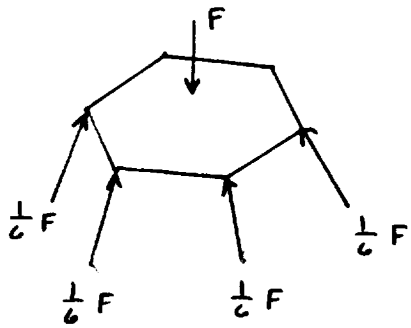
Materials Appendix

Typical properties of Derakane 8084 compared to standard vinyl ester resins

Properties	Derakane 8084	Standard V.E. Resins
Brookfield Viscosity	375	500
Specific Gravity	1.02	1.04
Percent Styrene	40	45
Tensile Strength (psi)	1.0×10^4	1.2×10^4
Tensile Modulus (psi)	4.6×10^5	4.9×10^5
Percent Elongation	10 - 12	5 - 6
Flexural Strength (psi)	1.7×10^4	1.8×10^4
Flexural Modulus (psi)	4.4×10^5	4.5×10^5
Barcol Hardness	30	35

APPENDIX 2A

The truncated hexagonal pyramid distributes the load due to the crane or hook (top/bottom).

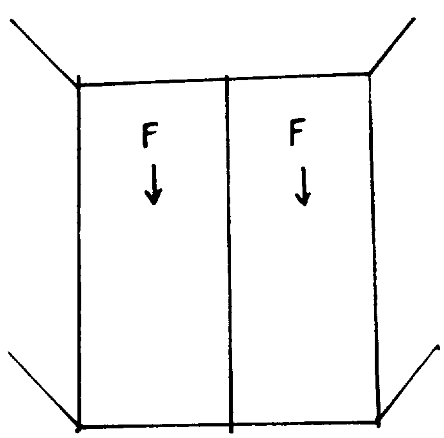


F = 1000 lb (crane load)

$$\sigma = \frac{F}{A} = \frac{1000 \text{ lb.}}{6'' \times \frac{1}{8}''} = 1350 \text{ psi}$$

Stress due to actuators on the side of the body

FBD:

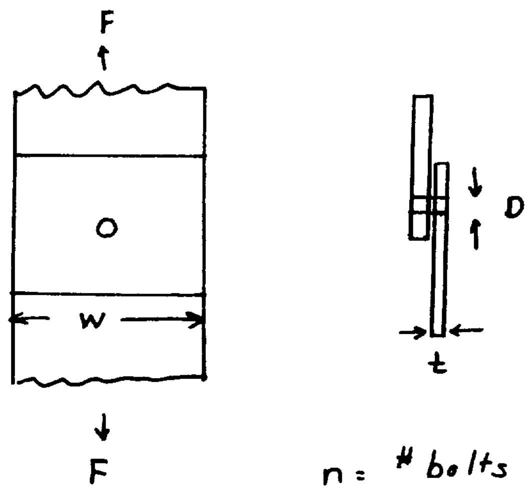


F = 1500 lb.

$$\sigma_{wall} = \frac{2F}{A} = \frac{(2)(1500 \text{ lb})}{12'' \times \frac{1}{8}''} = 2000 \text{ psi}$$

The fiberglass is easily capable of withstanding these stresses. The more crucial stresses are the shear stresses due to the bolt connections.

A tension splice using bolts can fail in one of three ways: bearing failure, shear failure, or tension failure.



For one bolt:

$$\sigma_{bear} = \frac{F}{Dt}$$

$$\sigma_{shear} = \frac{F}{\frac{1}{4}\pi D^2}$$

$$A_t = t(W - nD)$$

$$\sigma_{tension} = \frac{F}{A_t}$$

At the actuator connection:

$F = 1500$ lb. $\quad t = \frac{1}{8}$ in.

$D = 0.25$ in. $\quad W = 6$ in.

$$\sigma_{bear} = \frac{(1500 \text{ lb})}{(.25 \text{ in})(.125 \text{ in})} = 48{,}000 \text{ psi}$$ since $n = 4$, $\sigma_{bolt} = 12{,}000$ psi

$$\sigma_{shear} = \frac{(1500 \text{ lb})}{.25\pi(.25 \text{ in})^2} = 30{,}550 \text{ psi}$$ ... $\sigma_{bolt} = 7700$ psi

$$A_t = (.125 \text{ in.})(6 \text{ in.} - 4(.25)) = .625 \text{ in}^2$$

$$\sigma_{ten} = \frac{1500 \text{ lb}}{.625 \text{ in}^2} = 2400 \text{ psi/bolt}$$

Stress due to connection between fiberglass body and aluminum plate.

$F = 3000$ lb. $t = .125$ in. $n = 8$

$D = .25$ in. $W = 12$ in.

$$\sigma_{bear/bolt} = \frac{(3000\ \text{lb.})}{(.25\text{in})(.125\text{ in})(8)} = 12{,}000 \text{ psi}$$

$$\sigma_{shear/bolt} = \frac{(3000\ \text{lb})}{(8)(\frac{1}{4}\pi)(.25\text{in})^2} = 7700 \text{ psi}$$

$$\sigma_{tension} = \frac{3000\ \text{lb}}{(.125\text{in})(6\text{in} - 8(.25\text{in}))} = 12{,}000 \text{ psi}$$

For ANSI B18.3.1 standard $\frac{1}{4}$ in. diameter bolts.

$\sigma_{bear\ (allow)} = 33{,}000$ psi

$\sigma_{shear\ (allow)} = 21{,}000$ psi

$\sigma_{tension\ (allow)} = 36{,}000$ psi

Therefore, the bolts and material (body) can handle the loads.

APPENDIX 2B

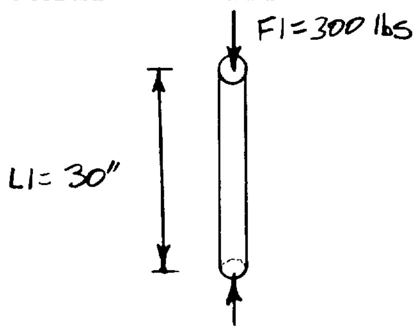
Stress and Buckling of Legs

Assumptions:

- Elastic theory
- 300 pound model
- 30-in. legs
- Homogeneous material
- Uniform transmission of forces from femur to tibia

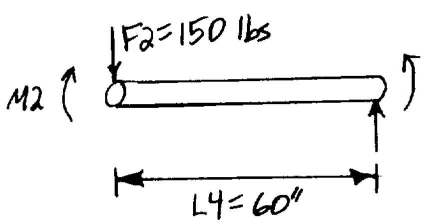
I. Analysis

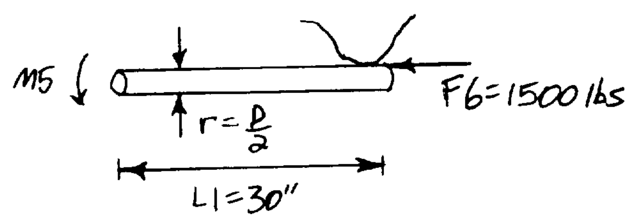
[A] Axial Stresses: Worst case --> standing on one leg



$$\boxed{\sigma = \frac{F1}{A} = \frac{300}{A}}$$

[B] Bending Stresses: worst case --> legs at 180 degrees, all weight on one leg (dynamic modeling)

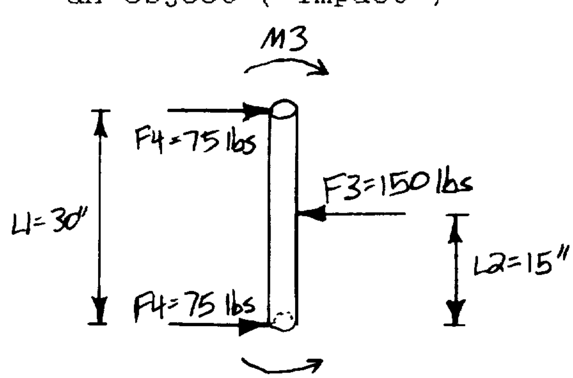




$$\boxed{\sigma = \frac{Mc}{I} = \frac{9000c}{I}}$$

$$\boxed{\sigma = \frac{Mc}{I} = \frac{1500rc}{I}}$$

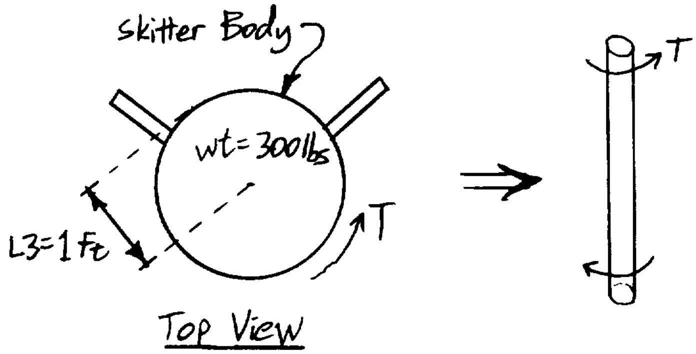
[C] Traverse Stresses: worst case --> SKITTER crashes into an object (impact)



$$\boxed{\sigma = \frac{Mc}{I} = \frac{1125c}{I}}$$

Buckling is not a consideration.

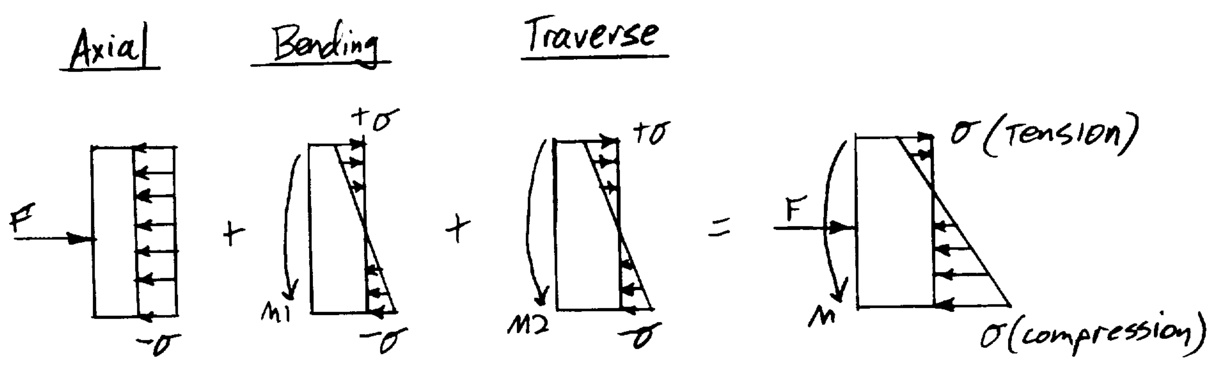
[D] Torsional Stresses: worst case --> one or two legs remains stationary while the other leg(s) moves tangentially

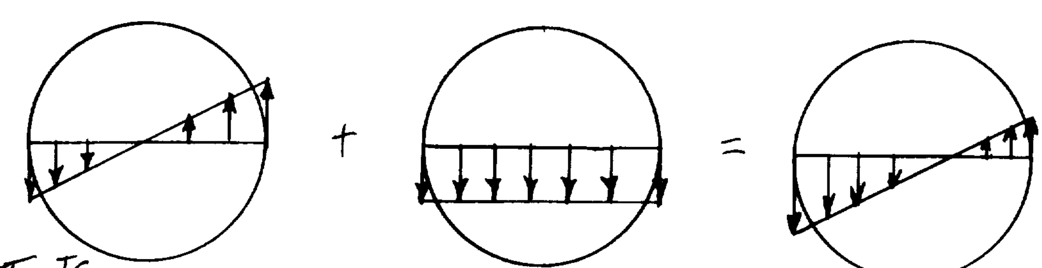


$$\boxed{\tau = \frac{Tc}{J} = \frac{1800c}{J}}$$

II. Summation :

By using the principle of superposition, the addition of all the stresses and an application of a Mohr's circle diagram to relate the shear and the other stresses will yield a single principal stress and a principal shear.

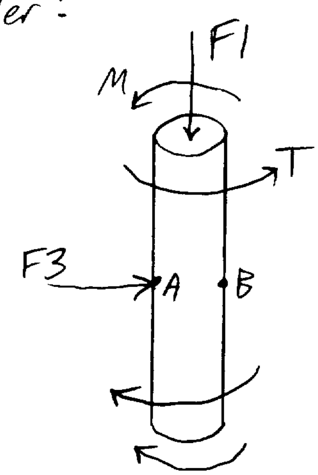




$\tau = \frac{Tc}{J}$ $\tau = \frac{4V}{3A} = \frac{4(150+75)}{3A}$ $\tau = \frac{Tc}{J} + \frac{4V}{3A}$

Sample Calculations (Legs)

For a 4"ϕ, $\frac{1}{8}$" thick, 30" long cylinder:



$$A = \frac{\pi}{4}\left(d_o^2 - d_i^2\right) = 1.5217 \text{ in}^2$$

$$k = \sqrt{\frac{d_o^2 + d_i^2}{16}} = 1.3707 \text{ in.}$$

$$I = kA^2 = 2.859 \text{ in}^4$$

$$J = \frac{\pi}{32}\left(d_o^4 - d_i^4\right) = 5.7183 \text{ in}^4$$

$$c = \frac{d}{2} = 2 \text{ in.}$$

Axial : $\sigma = \frac{F1}{A} = \frac{300}{A} = 197$ psi

Traverse: $\sigma = \frac{Mc}{I} = \frac{1125c}{I} = 787$ psi

Bending : $\sigma_1 = \frac{Mc}{I} = \frac{9000c}{I} = 6296$ psi

$\sigma_2 = \frac{Mc}{I} = \frac{3000c}{I} = 2099$ psi

Torsion : $\tau_{xy} = \frac{Tc}{J} + \frac{4V}{3A} = \frac{1800c}{J} + \frac{4(225)}{3A} = 827$ psi

Total $\sigma_{Tension} = \sigma_{Bend} - \sigma_{Axial} + \sigma_{trav} = 8985$ psi

Total $\sigma_{compr} = -(\sigma_{Bend} + \sigma_{axial} + \sigma_{trav}) = -9379$ psi

On tension side of leg (pt. B)	On compression side of leg (Pt. A)
$\tau_{max} = \sqrt{\left(\frac{\sigma_{tension}}{2}\right)^2 + \tau_{xy}^2} = 4568$ psi	$\tau_{max} = \sqrt{\left(\frac{\sigma_{compr}}{2}\right)^2 + \tau_{xy}^2} = 4762$ psi
$\sigma_{max} = \frac{\sigma_{tension}}{2} + \sqrt{\left(\frac{\sigma_{tens}}{2}\right)^2 + \tau_{xy}^2} = 9059$ psi	$\sigma_{max} = \frac{\sigma_{compr}}{2} - \sqrt{\left(\frac{\sigma_{compr}}{2}\right)^2 + \tau_{xy}^2} = -9451$ psi
$\sigma_{min} = \frac{\sigma_{tens}}{2} - \sqrt{\left(\frac{\sigma_{tens}}{2}\right)^2 + \tau_{xy}^2} = -76$ psi	$\sigma_{min} = \frac{\sigma_{compr}}{2} + \sqrt{\left(\frac{\sigma_{compr}}{2}\right)^2 + \tau_{xy}^2} = 73$ psi

$$\boxed{\begin{array}{l} \sigma_{max}(\text{compr}) = -9451 \text{ psi} \\ \sigma_{max}(\text{tens}) = 9059 \text{ psi} \\ \tau_{max} = 4762 \text{ psi} \end{array}}$$

```
  PROGRAM STRESS (INPUT,OUTPUT)
****************************************
* STRESS ANALYSIS ON SKITTER'S LEGS    *
****************************************
  REAL L1,L2,L3,M2,M3,M4,DIA(6,3),THICK(6,3),R(6,3),A(6,3),K(6,3),
 +I(6,3),J(6,3),C(6,3),T(6,3),SA(6,3),M5(6,3),MT(6,3),SB(6,3),
 +SC(6,3),T1(6,3),S1(6,3),C1(6,3),T2(6,3),ST(6,3),L4
  INTEGER W
  F1=300.
  L1=20.
  PRINT*,'LENGTH OF LEG= ',L1,' IN.'
  PRINT*,'TABLE OF MAXIMUM STRESSES AND SHEARS WITHIN THE LEG'
  PRINT*,'-----------------------------------------------------------'
  L2=L1/2.
  L3=12.
  L4=L1*2.
  F2=F1/2.
  M2=F2*L4
  F3=150.
  F4=F3/2.
  M3=F4*L2
  M4=F2*L3
  F6=1500.
  V=F2+F4
  PRINT 30
30 FORMAT (1X,'DIAMETER  THICKNESS    AREA    MAX. PRINCIPAL',
  +          '  MAX. PRINCIPAL    MAX. PRINCIPAL')
  PRINT 40
40 FORMAT (1X,'  (IN)        (IN)      (IN*IN)    C.STRESS(PSI)  ',
  +          '  T.STRESS (PSI)    SHEAR (PSI)   ')
  PRINT 50
50 FORMAT (1X,'-------------------------------------------------',
  +          '----------------------------------')
  DO 10 N=1,6
   DO 20 W=1,3
   DIA(N,W)=REAL(N)+2.
   THICK(N,W)=.125+(REAL(W)-1)*.0625
   R(N,W)=DIA(N,W)-2.*THICK(N,W)
   A(N,W)=3.14159*(DIA(N,W)**2-R(N,W)**2)/4.
   K(N,W)=SQRT((DIA(N,W)**2+R(N,W)**2)/16.)
   I(N,W)=A(N,W)*(K(N,W)**2)
   J(N,W)=I(N,W)*2.
   C(N,W)=DIA(N,W)/2.
   T(N,W)=(M4*C(N,W)/J(N,W))+(4.*V/(3.*A(N,W)))
   SA(N,W)=F1/A(N,W)
   M5(N,W)=DIA(N,W)*F6/2.
   MT(N,W)=M5(N,W)+M2+M3
   SB(N,W)=MT(N,W)*C(N,W)/I(N,W)
   SC(N,W)=-(SA(N,W)+SB(N,W))
   ST(N,W)=SB(N,W)-SA(N,W)
   T1(N,W)=SQRT((SC(N,W)/2.)**2+T(N,W)**2)
   T2(N,W)=SQRT((ST(N,W)/2.)**2+T(N,W)**2)
   S1(N,W)=SC(N,W)/2.-T1(N,W)
   C1(N,W)=ST(N,W)/2.+T2(N,W)
   PRINT 70, DIA(N,W), THICK(N,W), A(N,W), S1(N,W),C1(N,W),T1(N,W)
70 FORMAT (1X,F4.0,8X,F5.4,5X,F4.2,8X,F7.0,8X,F6.0,12X,F6.0)
20 CONTINUE
10 CONTINUE
   END
```

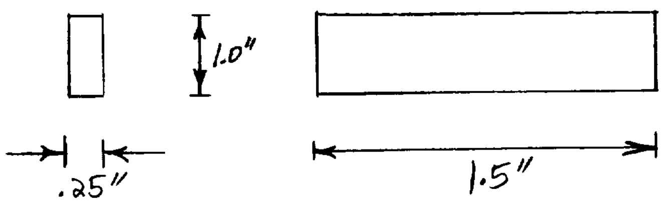
LENGTH OF LEG= 20. IN.
TABLE OF MAXIMUM STRESSES AND SHEARS WITHIN THE LEG

DIAMETER (IN)	THICKNESS (IN)	AREA (IN*IN)	MAX. PRINCIPAL C.STRESS (PSI)	MAX. PRINCIPAL T.STRESS (PSI)	MAX. PRINCIPAL SHEAR (PSI)
3.	.1250	1.13	-11985.	11462.	6077.
3.	.1875	1.66	-8504.	8147.	4311.
3.	.2500	2.16	-6790.	6516.	3441.
4.	.1250	1.52	-7113.	6725.	3605.
4.	.1875	2.25	-4967.	4704.	2517.
4.	.2500	2.95	-3903.	3702.	1977.
5.	.1250	1.91	-4832.	4523.	2448.
5.	.1875	2.83	-3343.	3134.	1693.
5.	.2500	3.73	-2602.	2443.	1317.
6.	.1250	2.31	-3564.	3308.	1805.
6.	.1875	3.42	-2450.	2277.	1240.
6.	.2500	4.52	-1895.	1764.	959.
7.	.1250	2.70	-2778.	2558.	1406.
7.	.1875	4.01	-1901.	1753.	962.
7.	.2500	5.30	-1463.	1352.	741.
8.	.1250	3.09	-2251.	2060.	1139.
8.	.1875	4.60	-1535.	1407.	777.
8.	.2500	6.09	-1178.	1081.	596.

LENGTH OF LEG= 30. IN.
TABLE OF MAXIMUM STRESSES AND SHEARS WITHIN THE LEG

DIAMETER (IN)	THICKNESS (IN)	AREA (IN*IN)	MAX. PRINCIPAL C.STRESS (PSI)	MAX. PRINCIPAL T.STRESS (PSI)	MAX. PRINCIPAL SHEAR (PSI)
3.	.1250	1.13	-16273.	15746.	8198.
3.	.1875	1.66	-11550.	11190.	5818.
3.	.2500	2.16	-9224.	8949.	4646.
4.	.1250	1.52	-9451.	9059.	4761.
4.	.1875	2.25	-6601.	6336.	3326.
4.	.2500	2.95	-5188.	4986.	2614.
5.	.1250	1.91	-6300.	5989.	3174.
5.	.1875	2.83	-4359.	4149.	2196.
5.	.2500	3.73	-3394.	3234.	1709.
6.	.1250	2.31	-4571.	4313.	2303.
6.	.1875	3.42	-3143.	2969.	1583.
6.	.2500	4.52	-2431.	2299.	1225.
7.	.1250	2.70	-3511.	3290.	1769.
7.	.1875	4.01	-2403.	2255.	1211.
7.	.2500	5.30	-1850.	1738.	932.
8.	.1250	3.09	-2809.	2616.	1415.
8.	.1875	4.60	-1916.	1787.	965.
8.	.2500	6.09	-1470.	1373.	741.

Sample Calculations (Knee)



Area $= bh = .25 \text{ in}^2$

$I = \frac{bh^3}{12} = .021 \text{ in}^4$

$c = \frac{h}{2} = .5 \text{ in.}$

$T_s = 70 \text{ kpsi}$

Material A92014

Knee (Tibia Side)

Case 1: Skitter supported by legs in a horizontal position.

$$\sigma = \frac{Mc}{I} = \frac{1000c}{I} = 25 \text{ kpsi}$$

$$n = \frac{T_s}{\sigma} = 2.8$$

Case 2: Movement of the leg.

$$\sigma = \frac{F}{A} + \frac{Mc}{I} = \frac{50}{A} + \frac{1045c}{I} = 26.3 \text{ kpsi}$$

$$n = \frac{T_s}{\sigma} = 2.7$$

Knee (Femur Side)

Case 1: Compression in the femur due to chain tension.

$$F = \frac{M \text{ in knee}}{r \text{ of gear}} = \frac{6274}{2(1.36)} = 2305 \text{ lbs (compression)}$$

$$\sigma = \frac{F}{A} = \frac{2305}{A} = 9220 \text{ psi}$$

$$n = 7.6$$

Hip

Case 1: Skitter supported by legs in a horizontal position.

$$\sigma = \frac{Mc}{I} = \frac{3140c}{I} = 58.9 \text{ kpsi}$$

$$n = 1.2$$

APPENDIX 2D

WEIGHT OF POWER TRANSMISSION

Part Description	Quantity Req'd.	Unit Wt.	Total Wt.
#35, ANSI Chain	23.85 ft.	0.23 lb/ft	5.4855 lb
#40, ANSI Chain	17.28 ft.	0.41 lb/ft	7.0848 lb
#40-2, ANSI Chain	4.38 ft.	0.82 lb/ft	3.5916 lb
Sprockets:			
35B70	3	4.7 lb	14.1 lb
35B12	3	0.1 lb	0.3 lb
35B35	6	1.5 lb	9.0 lb
40B17	6	0.9 lb	5.4 lb
D40B11	6	0.4 lb	2.4 lb
DS40A17	3	2.8 lb	8.4 lb
Bearings:			
VPS-116M	42	0.9 lb	35.0 lb
Vs-210	42	0.48 lb	20.2 lb
Shafts:			
3/4", 60 kpsi	132 in.	0.125 lb/in	16.5 lb
Actuators	6	15.0 lb	90.0 lb
Total Weight :			**216.8 lb**

CENTER DISTANCE SAMPLE CALCULATION

$L \equiv$ Length in chain pitches
$C \equiv$ Center distance
$N \equiv$ # of teeth on large sprocket
$n \equiv$ # of teeth on small sprocket
$P \equiv$ Chain pitch

$$L = \frac{2C}{P} + \frac{N+n}{2} + \frac{0.1013(N-n)^2}{4C}$$

Assume nominal value of C and solve for L. Round up to nearest integer value. Solve above equation for C.

$$\frac{2}{P}C^2 + \left(\frac{N+n}{2} - L\right)C + \frac{0.1013(N-n)^2}{4} = 0$$

$$C = \frac{-\left(\frac{N+n}{2} - L\right) \pm \sqrt{\left(\frac{N+n}{2} - L\right)^2 - 4\left(\frac{2}{P}\right)\left(\frac{0.1013(N-n)^2}{4}\right)}}{(4/P)}$$

TIBIA		OD	PD	Wt	Max. Bore
1 No. 35B12	$N=12$	1.62"	1.449"	0.1 lbs	3/4"
1 No. 35B35	$N=35$	4.39"	4.183"	1.5 lbs	1 5/8"
1 No. DS40A17	$N=17$	2.96"	2.721"	2.8 lbs	1 7/16"
2 No. 40B17	$N=17$	2.96"	2.721"	0.9 lbs	1 7/16"

$$C_{approx} = 8'' + \frac{PD_{35B12} + PD_{35B35}}{2} = 10.816''$$

$$L = \frac{2(10.816)}{0.375} + \frac{35+12}{2} + \frac{0.1013(35-12)^2}{4(10.816)} = 82.42 \text{ pitch lengths}$$

Use $\underline{L = 83}$ pitch lengths

$$\frac{2}{0.375}C^2 + \left(\frac{35+12}{2} - 83\right)C + 0.1013\frac{(35-12)^2}{4} = 0$$

$$5.33C^2 + (-59.5)C + 13.39693 = 0$$

$$C = \frac{59.5 \pm \sqrt{(59.5)^2 - 4(13.39693)(5.33)}}{(10.667)}$$

$$\boxed{\begin{array}{l} C = 10.93'' \\ L = 31.2'' = 2.6\,ft \end{array}}$$

$$C_{approx} \cong R_{40B17} + R_{DS40A17} + \frac{1}{8}$$

$$= 2.96'' + 0.125'' = 3.085''$$

$$L = \frac{2(3.085)}{0.5} + 17 = 29.34 \text{ pitch lengths} \approx 30 \text{ pitch lengths}$$

$$4C^2 + (17-30)C = 0$$

$$\boxed{\begin{array}{l} C = 5.0'' \\ L = 18.5'' \end{array}}$$

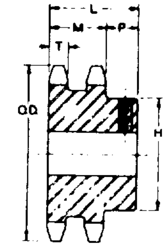
$$L = \frac{2(20)}{0.5} + 17 = 97 \text{ pitches}$$

$$\boxed{\begin{array}{l} C = 20'' \\ L = 48.5'' = 4.04 \text{ ft} \end{array}}$$

Steel Double Type "B" Minimum Bore Sprockets

Table No. 3 HARDENED TEETH

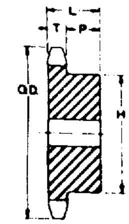
Part No.	DIAMETERS Outside	DIAMETERS Pitch	No. Teeth	Type	BORE Stock	BORE Max.*	DIMENSIONS T	DIMENSIONS M	DIMENSIONS L Max.	DIMENSIONS P	DIMENSIONS H	Wt Lbs
D40B11	2.00"	1.775"	11	DBS	1/2"	3/4"	.275"	.841"	1 1/2"	21/32"	1 7/16"†	.4
D40B17	2.96	2.721	17	DBS	5/8	1 7/16	.275	.841	1 1/2	21/32	2 1/8	1.5



TYPE DBS

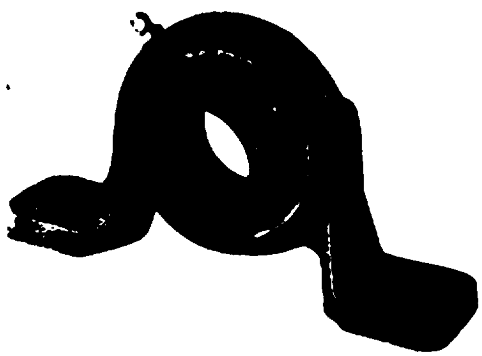
Table No. 2 Steel Type "B" Minimum Bore Single Sprockets

Part No.	DIAMETERS Outside	DIAMETERS Pitch	No. Teeth	Type	BORE Stock	BORE Max.*	DIMENSIONS T Nom.	DIMENSIONS L Max.	DIMENSIONS P	DIMENSIONS H	Wt. Lbs.
15B12	1.62	1.449	12	B	1/2	[illegible]	.188	3/4	47/64	1 7/16†	.1
15B35	4.38	4.183	35	B	1/2	1 5/8	.188	[illegible]	43/64	2 1/4	1.5
35B70	8.58	8.348	70	B	5/8	2	.188	27/32	43/64	3	4.7
40B17	2.96	2.721	17	B	5/8	1 7/16	.284	7/8	19/32	2 5/16	.9



TYPE B

Light Duty (100 Series)



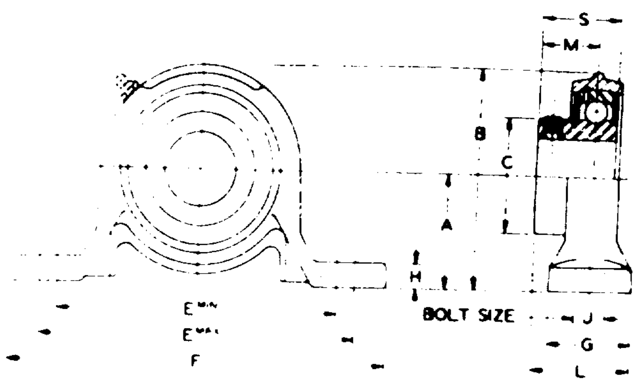
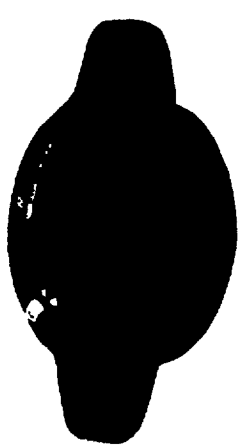


Table No. 20—Valuline Light Duty Pillow Blocks—Setscrew Lock—Malleable Housing

Shaft Size	Part Number	Dimensions A	B	C	E Min	E Max	F	G	H	J	L	M	S	Wt Lbs
3/4	VPS-112M	1 5/16	2 7/16	1 9/64	3 11/32	3 31/32	4 3/8	1 1/16	7/8	3/8	1 1/4	29/32	1 1/16	1.0
1	VPS-116M	1 7/16	2 11/16	1 11/32	3 25/32	4 5/32	5	1 1/8	13/32	3/8	1 21/64	49/64	1 7/64	1.0



drill out to 3/8"

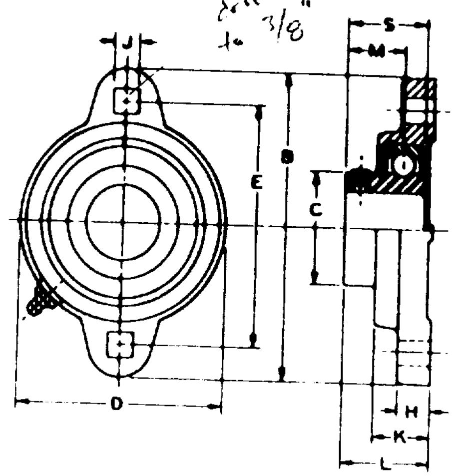


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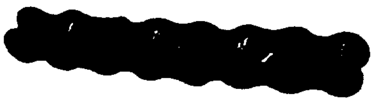
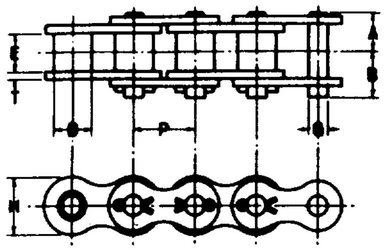
Table No. 21—Valuline Light Duty Flange Blocks—2-Hole—Setscrew Lock—Malleable Housing

Shaft Size	Part Number	Dimensions B	C	D		H	J	K	L	M	S	Wt. Lbs.
3/4	VF2B-112M	3 9/16	1 9/64	2 1/4	2 [illegible]	[illegible]	11/32	23/32	1 1/8	23/32	1 1/16	.6
1	VF2B-116M	3 3/4	1 11/32	2 1/2	3	7/16	11/32	25/32	1 3/16	49/64	1 7/64	.8

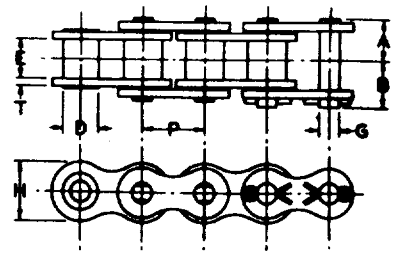
Single Strand—Riveted



Single Strand—Cottered



Roller Chain

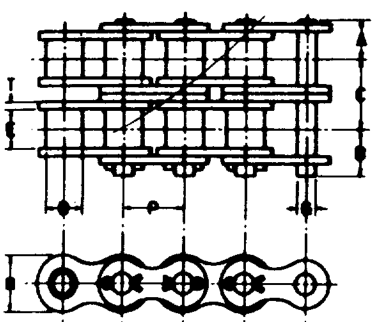


LL Chain

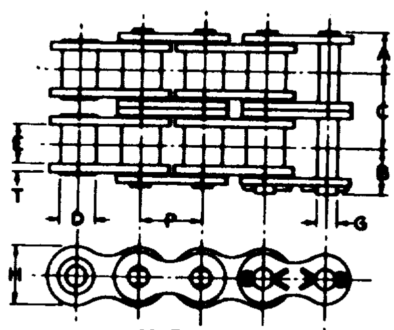
Table No. 1

Specifications — Single Strand Roller Chain

Chain Pitch P	Chain No.	CHAIN: Average Tensile Strength Lbs.	CHAIN: Average Weight per Ft. Lbs.	DIMENSIONS: Connecting Links A	Connecting Links B	Rollers D	Rollers E	Pins G	Side Plates H	Side Plates T
3/8	35	2,100	.23	.228	.286	.200	3/16	.141	.344	.050
1/2	40	3,700	.41	.314	.373	.312	5/16	.156	.468	.060

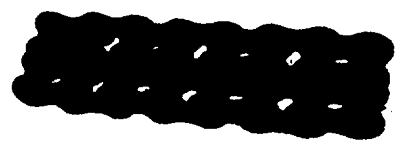


Roller Chain



LL Chain

Double Strand—Riveted

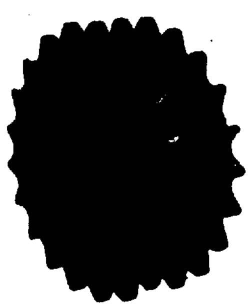


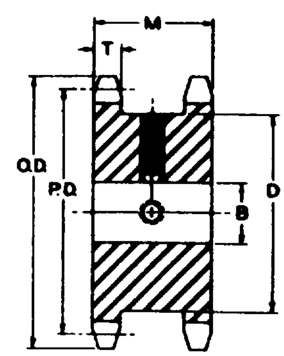
Double Strand—Cottered

Table No. 1

Specifications — Double Strand Roller Chain

Chain Pitch P	Chain No.	CHAIN: Average Tensile Strength Lbs.	CHAIN: Average Weight per Ft. Lbs.	DIMENSIONS: Connecting Links A	Connecting Links B	Spacing C	Rollers D	Rollers E	Pins G	Side Plates H	Side Plates T
1/2	40-2	7,400	.82	.314	.373	.566	.312	5/16	.156	.468	.060





TYPE DS-A

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Table No. 1

Stock Steel Type "A" Double Single Sprockets

Part No	DIAMETERS: O.D.	DIAMETERS: P.D.	DIAMETERS: D	Type	No. Teeth	Bore "B": Stock	Bore "B": Max.	DIMENSIONS: M	DIMENSIONS: T	Wt. Lbs.
For No. 40, 1/2" Pitch Standard Single Strand Roller Chain										
DS40A17	2.96"	2.721"	2 9/64"	DS-A	17	1/2"	1 7/16"	1 13/32"	.284"	2 8

APPENDIX II

ALTERNATIVE DESIGNS

Through the course of our design process, we encountered or devised alternatives to our final design. Below is an enumeration of these alternatives.

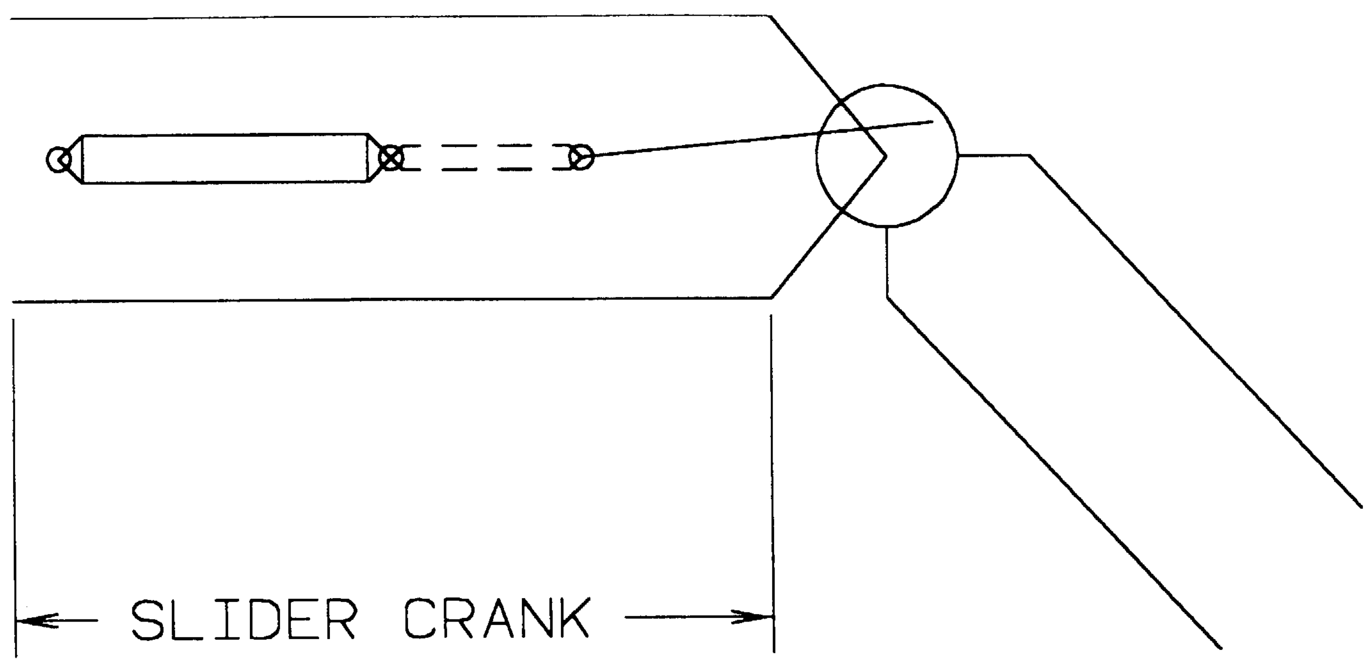
* The use of a slider-crank for the power transmission system.

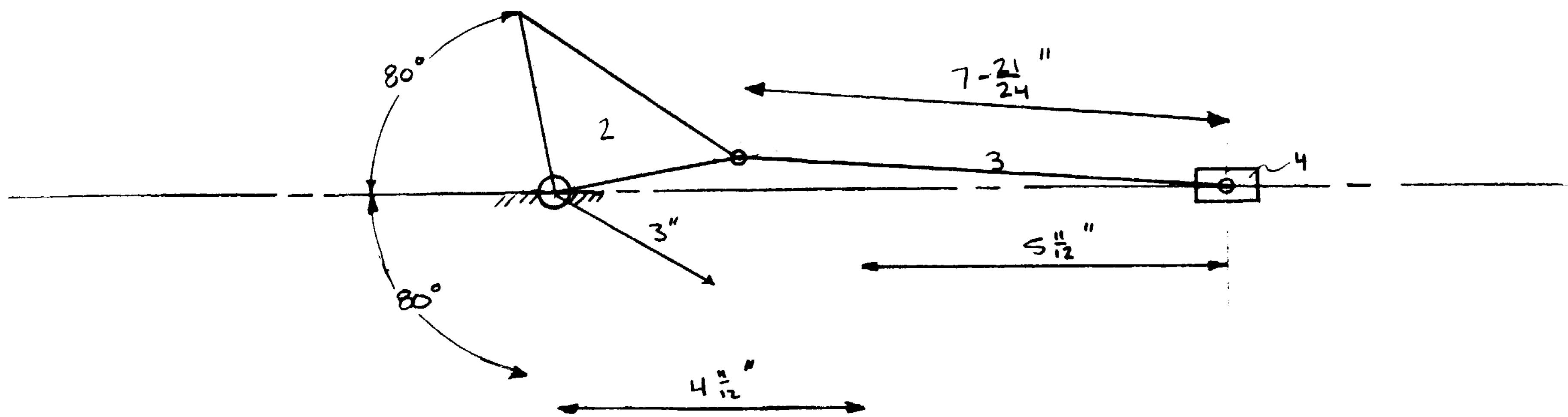
  The slider-crank mechanism has advantages of simplicity , reduced weight, and the need for fewer mechanical parts. Diadvantages for the slider-crank are the dead spots in the range of motion and the relatively large size requirements in the legs for the assembly. (See figure and program)

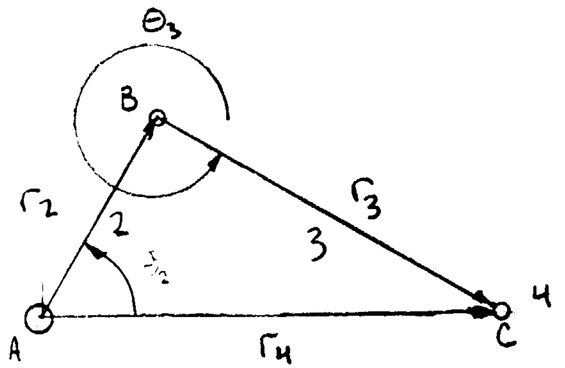
* The use of rotarary actuators instead of the linear ones.

  Advantages of the rotary actuators are the lighter weight, the lesser number of components needed for transmission of torques, lower noise than the chains and sprockets will generate, smaller body dimensions,easier assembly, and the use of the actuator as the joint itself.

  Disadvantages of the rotary actuators are the need to reinforce the joint area to attach the actuator to the joint, may not provide necessary acceleration for movement, and the need to redesign the joint from the linear actuators.


SLIDER CRANK





$$\bar{r}_4 = \bar{r}_2 + \bar{r}_3$$
$$\theta_3 = -\sin^{-1}[(r_2/r_3)\sin\theta_2]$$
$$r_4 = r_2\cos\theta_2 + r_3\cos\theta_3$$
$$\dot{\theta}_2 = \dot{r}_4 / [r_3 r_2 \cos\theta_2 \tan\theta_3 - r_2\sin\theta_2]$$
$$\dot{\theta}_3 = (-r_2\cos\theta_2)\dot{\theta}_2 / r_3\cos\theta_3$$

```
PROGRAM ME4182

       Robert Montgomery      Design Group 2
*
*      This program does a position, velocity, acceleration, and
*      force analysis on a slider crank mechanism proposed for the
*      joints of Skitter II.
*
*      The equations used for the position, velocity, and acceleration
*      calculations were derived from those given on pages 148 and 149
*      of Shigley and Uicker's "Theory of Machines and Mechanisms".
*
*      The program requires as inputs the lengths of links two and
*      three, the angle that link two makes with the horizontal, and
*      the linear velocity and acceleration of link four.
*

      REAL R2, R3, R4
      REAL THETA2, THETA3, PI
      REAL OMEGA2, OMEGA3, V4, ALPHA2, ALPHA3, A4
      INTEGER N

      PI = 4.0*ATAN(1.0)

      WRITE (*,*) ' Input the value of R2 - '
         READ (*,*) R2
      WRITE (*,*) ' Input the value of R3 - '
         READ (*,*) R3
      WRITE (*,*) ' Input the value of V4 - '
         READ (*,*) V4
      WRITE (*,*) ' Input the value of A4 - '
         READ (*,*) A4


      DO 10 I = 10,170,1
        THETA2 = PI*I/180
        THETA3 = (-1)*ASIN(R2*SIN(THETA2)/R3)
        R4 = R2*COS(THETA2) + R3*COS(THETA3)
        OMEGA2 = V4/(R3*R2*COS(THETA2)*TAN(THETA3) - R2*SIN(THETA2))
        OMEGA3 = (-1)*R2*COS(THETA2)*OMEGA2/(R3*COS(THETA3))
        A = R2*SIN(THETA2)*OMEGA2**2 + R3*SIN(THETA3)*OMEGA3**2
        B = -R2*COS(THETA2)*OMEGA2**2 - R3*COS(THETA3)*OMEGA3**2
        ALPHA2 = A4/(B - TAN(THETA3)*A)
        C = -R2*COS(THETA2)*ALPHA2 + R2*SIN(THETA2)*OMEGA2**2
        D = R3*SIN(THETA3)*OMEGA3**2
        ALPHA3 = (C + D)/(R3*COS(THETA3))
        THETA2 = 180*THETA2/PI
        THETA3 = 180*THETA3/PI
        WRITE (*,*) ' THETA2 = ',THETA2,'  DEGREES'
        WRITE (*,*) ' THETA3 = ',THETA3,'  DEGREES'
        WRITE (*,*) ' OMEGA2 = ',OMEGA2,'  RADIANS PER SECOND'
        WRITE (*,*) ' OMEGA3 = ',OMEGA3,'  RADIANS PER SECOND'
        WRITE (*,*) ' ALPHA2 = ',ALPHA2,'  RADIANS PER SECOND SQUARED'
        WRITE (*,*) ' ALPHA3 = ',ALPHA3,'  RADIANS PER SECOND SQUARED'
```

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SKITTER II - MONOCOQUE DESIGN

14 April 1988

FROM: TEAM 2

Rob Bansek	Greg Johnson
Andy Booth	Eric Lindzen
Steve Daneman	Koi Marcucelli
Jim Dresser	Bob Montgomery
Todd Haney	Andy Warren

TO: Mr. J. Brazell

SUBJ: WEEKLY REPORT --> WEEK #2

Mr Brazell:

For the weeks covering 31 Mar - 14 April 1988 our team accomplished the following tasks:

[1] Identified the major components and problems of the monocoque design for Skitter II. These include:

a) Joint design
b) Material considerations
c) Geometric configuration
d) Actuator connections

[2] Developed two potential designs for the joint connecting both the femor to the tibia and the femor to the main body. (See enclosed sketches of these designs.)

[3] Generated questions concerning the nature of the actuators, (i.e. their size, shape, length of travel of moving element, etc.)

[4] Decided to use VERSACAD and SUPERTAB as our drafting systems, and WORDPERFECT as our wordprocessor.

SKITTER II - MONOCOQUE DESIGN

21 April 1988

FROM: TEAM 2

Rob Bansek	Greg Johnson
Andy Booth	Eric Lindzen
Steve Daneman	Koi Marcucelli
Jim Dresser	Bob Montgomery
Todd Haney	Andy Warren

TO: Mr. J. Brazell

SUBJ: WEEKLY REPORT --> WEEK #3

Mr Brazell:

The following tasks were accomplished the week of 14 April-20 April 1988:

[1] Decided to concentrate our efforts on the slider-crank design for the joint .

[2] Used GTEC to access information concerning re-enforced monocoque designs.

[3] Initiated a search for information regarding fiberglass fasteners.

[4] Discussed problems concerning actuator placement and actuator range of mobility.

[5] Started a force and torque analysis of proposed slider crank joint mechanism.

[6] Developed a flow diagram for order of work on the project.

SKITTER II - MONOCOQUE DESIGN

28 April 1988

FROM: TEAM 2

Rob Bansek	Greg Johnson
Andy Booth	Eric Lindzen
Steve Daneman	Koi Marcucelli
Jim Dresser	Bob Montgomery
Todd Haney	Andy Warren

TO: Mr. J. Brazell

SUBJ: WEEKLY REPORT --> WEEK #4

Mr Brazell:

These are our accomplishments for the week of 22 - 28 April:

{1} Gathered information on the materials which includes properties, costs, and availability

{2} Analyzed various options for the power train and settled on the chain and sprocket method.

{3} Developed the tentative work/deadline schedule for the remaining time of the project.

{4} Developed a pie graph of jobs/sections for the project

{5} Initiated research on fiberglass fasteners

{6} Discussed with tool interface group to compare compatibility

{7} Began preliminary inquiries into geometries of femur and tibia

enclosure:schedule

SCHEDULE

WEEK 5 =>
* Decide on power transmission(general)
* Decide on material
* Gather information on required torques/forces for walking
* Discuss joint connections

WEEK 6 =>
* Analyze material costs, availability, properties
* Discuss proposed geometries
* Discuss proposed connections
* Discuss proposed joints

WEEK 7 =>
* Decide on geometry
* Decide on connections
* Decide on joints
* Complete required force/stress analysis on above

WEEK 8 =>
* Develop report outline
* Complete all CAD drawings
* Incorporate major sections into comprehensive design

WEEK 9 =>
* Write first draft of report
* Add any additional information/drawings

WEEK 10 =>
* Final report
* Prepare & give presentation

SKITTER II - MONOCOQUE DESIGN

5 May 1988

FROM: TEAM 2

Rob Bansek	Greg Johnson
Andy Booth	Eric Lindzen
Steve Daneman	Koi Marcucelli
Jim Dresser	Bob Montgomery
Todd Haney	Andy Warren

TO: Mr. J. Brazell

SUBJ: WEEKLY REPORT --> WEEK #5

Mr Brazell:

The following tasks were performed for the week 29 Apr - 5 May:

[1] Analyzed requirements for power train and decided preliminary design for power train including sizes of sprockets and chains

[2] Decided on geometry of legs and evaluated designs for geometry of body

[3] Produced initial design for joints and connection of joints to body

[4] Prepared presentation for class

SKITTER II - MONOCOQUE DESIGN

12 May 1988

FROM: TEAM 2

Rob Bansek
Andy Booth
Steve Daneman
Jim Dresser
Todd Haney
Greg Johnson
Eric Lindzen
Koi Marcucelli
Bob Montgomery
Andy Warren

TO: Mr. J. Brazell

SUBJ: WEEKLY REPORT --> WEEK #6

Mr Brazell:

For the weeks covering 6 May - 12 May 1988 our team accomplished the following tasks:

[1] Established an outline with deadlines for reports of sub-sections to be consolidated into the final report. These smaller groups are:

<u>Power transmission</u>

1. Gear size weight, and cost
2. Chain type
3. Why gears?
4. Required torques, forces
5. Summary of design process

<u>Body</u>

1. Size, shape, thickness, weight
2. Top
3. Internal frame
4. Why this frame shape?
5. Production
6. Summary of design process

<u>Materials</u>

1. Cost v. strength to weight ratios
2. Material properties
3. Cost and availability
4. Formation of model

Legs

1. Stress analysis
2. Required thickness of shell and cross-sectional geometry
3. Formation of parts
4. Summary of design process

SKITTER II - MONOCOQUE DESIGN

12 May 1988

FROM: TEAM 2

Rob Bansek	Greg Johnson
Andy Booth	Eric Lindzen
Steve Daneman	Koi Marcucelli
Jim Dresser	Bob Montgomery
Todd Haney	Andy Warren

TO: Mr. J. Brazell

SUBJ: WEEKLY REPORT --> WEEK #7

Mr Brazell:

The following was accomplished the week ending 12 May 1988:

[1] Made final decisiions on body geometry

[2] Made final decisions on leg geomtry

[3] Generated data for attachment of power transmission to body

[4] Completed force/torque analysis on joints and legs

SKITTER II - MONOCOQUE DESIGN

19 May 1988

FROM: TEAM 2

Rob Bansek
Andy Booth
Steve Daneman
Jim Dresser
Todd Haney
Greg Johnson
Eric Lindzen
Koi Marcucelli
Bob Montgomery
Andy Warren

TO: Mr. J. Brazell

SUBJ: WEEKLY REPORT --> WEEK #8

Mr Brazell:

The following was accomplished the week ending 19 May 1988:

[1] Developed the outline for the report

[2] Completed all the basic CAD drawings

[3] Incorporated the major report sections into a comprehensive blob

SKITTER II - MONOCOQUE DESIGN

26 May 1988

FROM: TEAM 2

Rob Bansek	Greg Johnson
Andy Booth	Eric Lindzen
Steve Daneman	Koi Marcucelli
Jim Dresser	Bob Montgomery
Todd Haney	Andy Warren

TO: Mr. J. Brazell

SUBJ: WEEKLY REPORT --> WEEK #9

Mr Brazell:

The following was accomplished the week ending 26 May 1988:

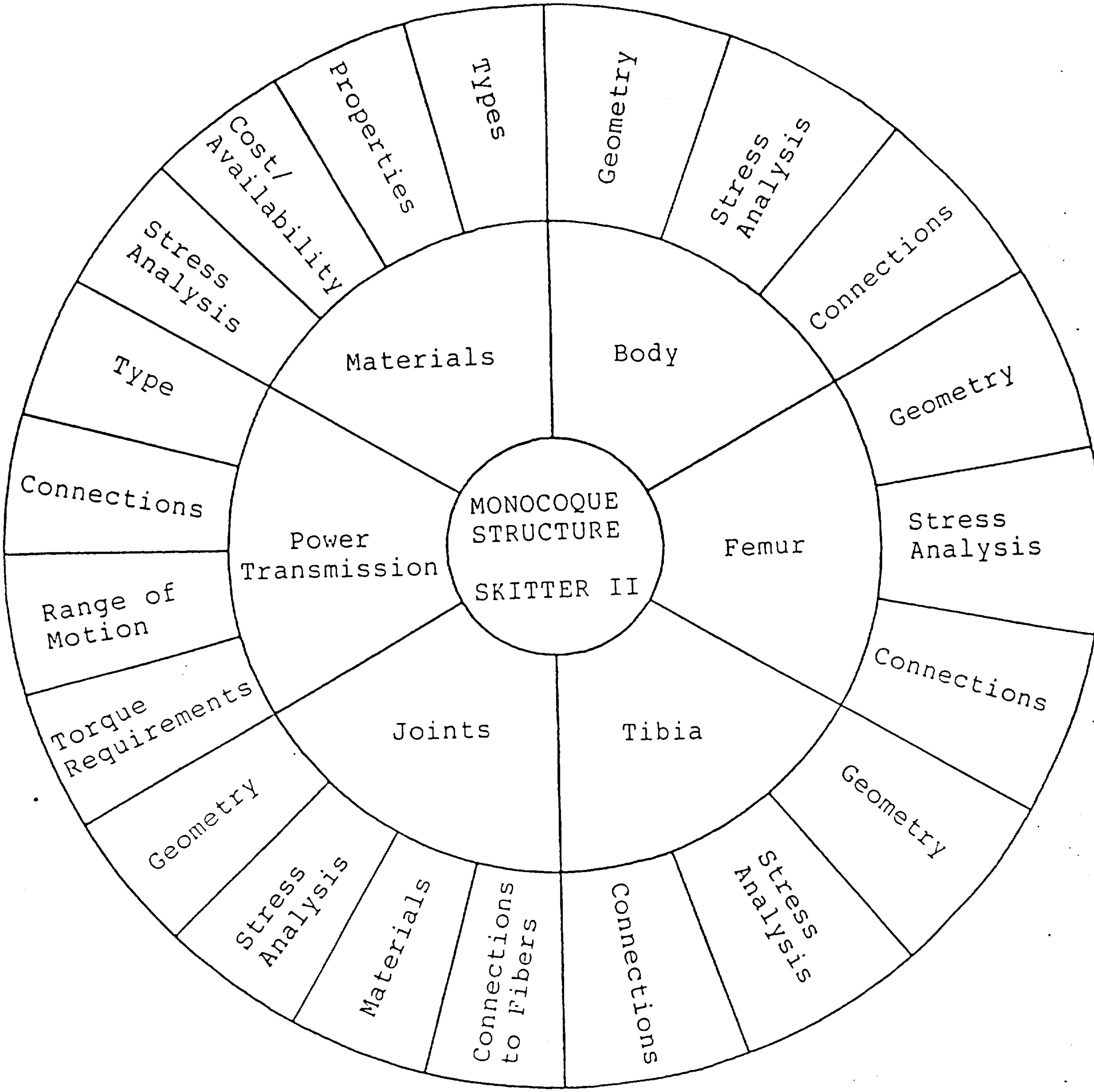
[1] Finalized all decisions for the design

[2] Completed analysis for major sections

[3] Isometric picture of entire walker begun

[4] Wrote computer program to analyze stresses in legs

[5] Wrote inital rough draft and reviewed analysis mini-reports



MONOCOQUE STRUCTURE
SKITTER II
Materials
Body
Femur
Tibia
Joints
Power Transmission
Types
Geometry
Stress Analysis
Connections
Geometry
Stress Analysis
Connections
Geometry
Stress Analysis
Connections
Connections to Fibers
Materials
Stress Analysis
Geometry
Torque Requirements
Range of Motion
Connections
Type
Stress Analysis
Cost/ Availability
Properties